Valley of the Winds

APPENDIX F
NOISE ASSESSMENT

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VALLEY OF THE WINDS WIND FARM
EIS NOISE ASSESSMENT

Rp 003 r01 20191254 | 23 February 2022

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Project: **Valley of the Winds wind farm**

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EXECUTIVE SUMMARY

This report presents the results of an assessment of environmental noise associated with the Valley of the Winds wind farm (the wind farm) that is proposed to be developed by UPC\AC Renewables Australia (UPC\AC) (the proponent).

The wind farm is proposed to comprise one hundred and forty-eight (148) wind turbines and related infrastructure. The proposed related infrastructure relevant to the environmental noise assessment includes battery energy storage systems, substations and a potential construction workforce accommodation facility.

The development application for the wind farm seeks permission to develop, construct and operate turbines with a maximum tip height of 250 m. The actual turbine which would be used at the site would be determined during the detailed design stage, following determination of the project. The final selection would be based on a range of design requirements including achieving compliance with the development consent noise limits at surrounding noise sensitive locations (receivers). In advance of a final selection, the assessment considers candidate turbine models that are representative of the size and type of turbine which could be used at the site. For this purpose, three candidate turbines have been nominated by the proponent for this assessment.

Operational noise from the proposed wind turbines has been assessed in accordance with the NSW Government publication *Wind Energy: Noise Assessment Bulletin* (NSW Noise Assessment Bulletin) as required by the applicable Planning Secretary's Environmental Assessment Requirements (SSD-10461), dated 9 June 2020.

A background noise monitoring survey was undertaken to obtain a representation of typical baseline conditions at receivers in the vicinity of the wind farm and derive applicable noise limits. The results are detailed in MDA report Rp 002 20191254 *Valley of the Winds Wind Farm - Background Noise Assessment*, dated 8 February 2022 (background noise report).

Manufacturer specifications for the candidate turbine models has been used as the basis for the assessment. The specifications for each turbine include noise emission data in accordance with the international standard[1] referenced in the NSW Noise Assessment Bulletin. The noise emission data used is consistent with the range of values expected for comparable types of multi megawatt wind turbine models that may be considered for the site.

The noise emission data has been used with international standard ISO 9613-2[2] to predict wind turbine noise levels at neighbouring receivers. The ISO 9613-2 standard has been applied using well-established input choices and adjustments, based on research and international guidance, that are specific to wind farm noise assessment.

The results of the noise modelling for the wind farm demonstrate that the predicted noise levels for the proposed turbine layout achieve the base (minimum) noise limit determined in accordance with the NSW Noise Assessment Bulletin at all of the assessed receivers for two of the three candidate turbine models. Using the GE 6.0-164 turbine model, wind turbine noise levels were predicted to comply with the applicable noise limits at all but one receiver where the noise limit at 10 m/s is marginally exceeded by up to 0.2 dB.

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1 IEC 61400-11:2012 *Wind turbines - Part 11: Acoustic noise measurement techniques*

2 ISO 9613-2 *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation*

To assess compliance with the applicable noise limits, the NSW Noise Assessment Bulletin requires consideration of potential adjustments to the predicted wind turbine noise levels for special noise characteristics, comprising tonality and low frequency. Analysis of the noise emission frequency data for the candidate turbines indicates the noise of the wind farm is not expected to be characterised by tonality. This is supported by evidence of operational wind farms in Australia which indicates that the occurrence of tonality at receivers is atypical. Indicative noise modelling also demonstrated that the wind farm is predicted to result in noise levels below 60 dB L_{Ceq} (the threshold defined by the NSW Noise Assessment Bulletin for the presence of low frequency). Accordingly, adjustments for special noise characteristics were not warranted and have therefore not been applied to the predicted noise levels.

The assessment results also demonstrate that cumulative noise considerations between the Valley of the Winds wind farm and the nearby Liverpool Range Wind Farm can be practically managed. Specifically, it was demonstrated that cumulative wind farm noise levels do not affect the compliance outcomes for either of the assessed projects.

The assessment has also considered operational noise from the proposed related infrastructure comprising a battery energy storage system and three substations. The predicted noise levels have been assessed in accordance with the NSW EPA *Noise Policy for Industry*. The assessment demonstrates that the related infrastructure is predicted to be substantially below the most stringent night-time project noise trigger level at all receivers.

The findings of the operational noise assessment therefore demonstrated support that the project can be designed and operated to comply with NSW requirements for both wind turbine noise and the related infrastructure. Prior to construction of the wind farm, the predicted noise levels are recommended to be updated for the final wind farm configuration and equipment selections in order to verify compliance with the criteria.

Consistent with the NSW Noise Assessment Bulletin, compliance is also recommended to be verified by post-construction noise compliance monitoring. The compliance testing procedures should be documented in an operational noise management plan. Given the size of the project, the compliance testing regime to be documented in the operational noise management plant is recommended to include provisions early onsite noise emission testing of the turbines to verify consistency with the design validation modelling.

A preliminary construction noise and vibration assessment has also been conducted, accounting for typical equipment items and work practices as well as details of the relevant NSW guidelines and preliminary noise management recommendations. The assessment was undertaken in accordance with the NSW DECC publications *Interim Construction Noise Guideline* and *Assessing Vibration: A Technical Guideline* and confirmed that a construction noise and vibration can be appropriately managed using standard good practice measures. An assessment of traffic noise impacts associated with construction operations has been conducted in accordance with the NSW EPA *Road Noise Policy*.

Measures for the management of construction noise and vibration would be implemented via a Construction Noise and Vibration Management Plan to be prepared at a later stage of the project, when a construction contractor has been selected and specialised construction planning for the site has been developed. This would comprise a detailed noise and vibration assessment, including consideration for blasting and construction traffic.

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1.0 INTRODUCTION

UPC Renewables Australia Pty Ltd, operating as UPC\AC Renewables Australia (the Proponent), proposes to construct, operate and decommission the Valley of the Winds wind farm (the project).

The project comprises approximately one hundred and forty-eight (148) wind turbines and related infrastructure. The proposed related infrastructure relevant to the environmental noise assessment comprises battery energy storage systems, substations and a construction workforce accommodation facility. Throughout this report, the term 'wind farm' refers to both the wind turbines and the related infrastructure.

This report presents the results of an assessment of operational and construction noise for the proposed wind farm undertaken in accordance with the applicable Planning Secretary's Environmental Assessment Requirements (SSD-10461), dated 9 June 2020 (SEARs), and the publications referenced within.

The assessment of operational noise associated with the wind turbines has been undertaken in accordance with the NSW EPA[3] *NSW Wind Energy: Noise Assessment Bulletin* dated December 2016 (NSW Noise Assessment Bulletin) as required by the SEARs.

Noise associated with the operation of the proposed related infrastructure has been assessed in accordance with the NSW EPA *Noise Policy for Industry* 2017 (NPfI) as required by the SEARs.

The noise assessment presented in this report is based on:

- Operational noise limits determined in accordance with applicable regulatory documentation;
- Predicted wind turbine noise levels, based on the proposed site layout and three candidate turbine models; and
- Predicted noise levels from the related infrastructure, based on assumed noise emission data.

As required by the NSW Noise Assessment Bulletin, background noise data has been acquired at representative receivers throughout the site. The background noise monitoring was undertaken as an element of the noise studies associated with the wind farm's development application to obtain a representation of typical baseline conditions at receivers in the vicinity of the wind farm and derive applicable noise limits.

Acoustic terminology used in this report is presented in Appendix A.

General information about the definition of sound and the ways that different sound characteristics are described is presented in Appendix B.

[3] Environment Protection Authority

1.1 Project overview

The project is proposed to be located close to the townships of Coolah and Leadville, with the transmission line running generally south to its connection with the Central-West Orana REZ Transmission line. The project would be entirely within the Warrumbungle Local Government Area.

The project would involve the construction, operation and decommissioning the following key components:

- Approximately one hundred and forty-eight (148) wind turbines with a maximum tip height of 250 metres and a hardstand area at the base of each turbine

  Three (3) clusters of wind turbines, that would be connected together electrically. These are:

  - Mount Hope cluster with approximately seventy-six (76) turbines;
  - Girragulang Road cluster with approximately fifty-one (51) turbines; and
  - Leadville cluster with approximately twenty-one (21) turbines.
- Electrical infrastructure, including:
  - a substation in each cluster and a step-up facility at the connection to the Central-West Orana REZ Transmission line;
  - underground 33 kilovolt electrical reticulation connecting the turbines to the substation in each cluster;
  - overhead transmission lines (up to 220 kilovolts) dispatching electricity from each cluster;
  - other electrical infrastructure as required including a potential battery energy storage system (BESS); and
  - a high voltage transmission line (up to 330 kilovolts) connecting the wind farm to the Central-West Orana Transmission line.
- Other permanent on-site ancillary infrastructure:
  - permanent operation and maintenance facilities; and
  - meteorological masts (up to thirteen).
- Access track network:
  - access and egress points to each cluster from public roads; and
  - operational access tracks and associated infrastructure within each cluster on private property.
- Temporary construction ancillary facilities:
  - construction compounds;
  - laydown areas;
  - concrete batching plants;
  - quarry sites for construction material (rock for access tracks and hardstands); and
  - a workers accommodation camp for 400 people.

The coordinates of the wind turbines are presented in tabular format in Appendix C. Details of the proposed candidate turbine models are presented in Section 5.2.

Site layout plans illustrating the turbine layout, related infrastructure and receivers are provided in Figure 1 to Figure 3, for each of the clusters.

1.2 Site context

The land surrounding the wind farm site is characterised by rolling pastoral hills, open flat valleys and ridgelines with scattered vegetation. The hill slopes are generally gentle in gradient and predominantly cleared of vegetation, except for patches of denser remnant vegetation on steeper terrain, near rocky outcrops and between saddles.

The topography of the site and surrounding area is depicted in the elevation map provided in Appendix A.

Land uses within the locality of the wind farm site include:

- farming – predominantly grazing cattle and sheep, with small patches of cropping (cereal and fodder); and
- rural living – scattered rural dwellings and sheds present throughout the landscape, with a higher density of dwellings in the townships.

The townships of Coolah and Leadville are the closest population centres to the wind farm site. These townships are located on gently sloping to level land within valleys near creeks. Most built structures are of low to moderate scale.

A total of fifty-seven (57) noise sensitive locations (receivers) have been identified by the proponent within 3 km of the project and considered in this noise assessment. This includes twenty-two (22) receivers where a noise agreement has been formalised between the landowners and the proponent, which are referred to as *associated receivers* herein. The remaining receivers, without an agreement with the proponent, are referred to as *non-associated receivers*.

The coordinates of the receivers identified within 3 km of the project are tabulated in Appendix E.

Ground truthing information provided by the proponent is limited to the identification of residential receivers only. Due to the rural setting, it is not expected that extensive non-residential receivers will be a feature of the wider site. Further, it is not expected that there would be extensive other type of sensitive receivers for the purpose of the operational assessment. However, a more detailed review of these receiver types may be appropriate at a later stage of the project. For the purposes of this planning risk assessment, evaluation of construction noise and vibration levels is limited to residential receivers only.

1.3 Purpose of this report

The capital value of the project would be more than $30 million. Accordingly, the project is a State significant development (SSD) under the *State Environmental Planning Policy (State and Regional Development) 2011* and Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). Under Section 4.12(8) of the EP&A Act, a development application for a State Significant Development must be accompanied by an environmental impact statement (EIS) that is lodged with the NSW Department of Planning, Industry and Environment for development consent.

The project was also referred to the Commonwealth Department of Agriculture, Water and the Environment in recognition of potential impacts to matters of national environmental significance protected by the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). On 13 July 2020, a delegate of the Federal Minister for the Department of Agriculture, Water and the Environment determined that the project was a controlled action under Section 75 of the EPBC Act and therefore requires assessment and approval under the EPBC Act. Accordingly, the EIS for the project is being prepared under the *Amended Bilateral Agreement* between the Department of Agriculture, Water and the Environment and the Department of Planning, Industry and Environment.

This report has been prepared to inform the EIS and development application for the project.

Figure 1: Site layout – Mount Hope Cluster

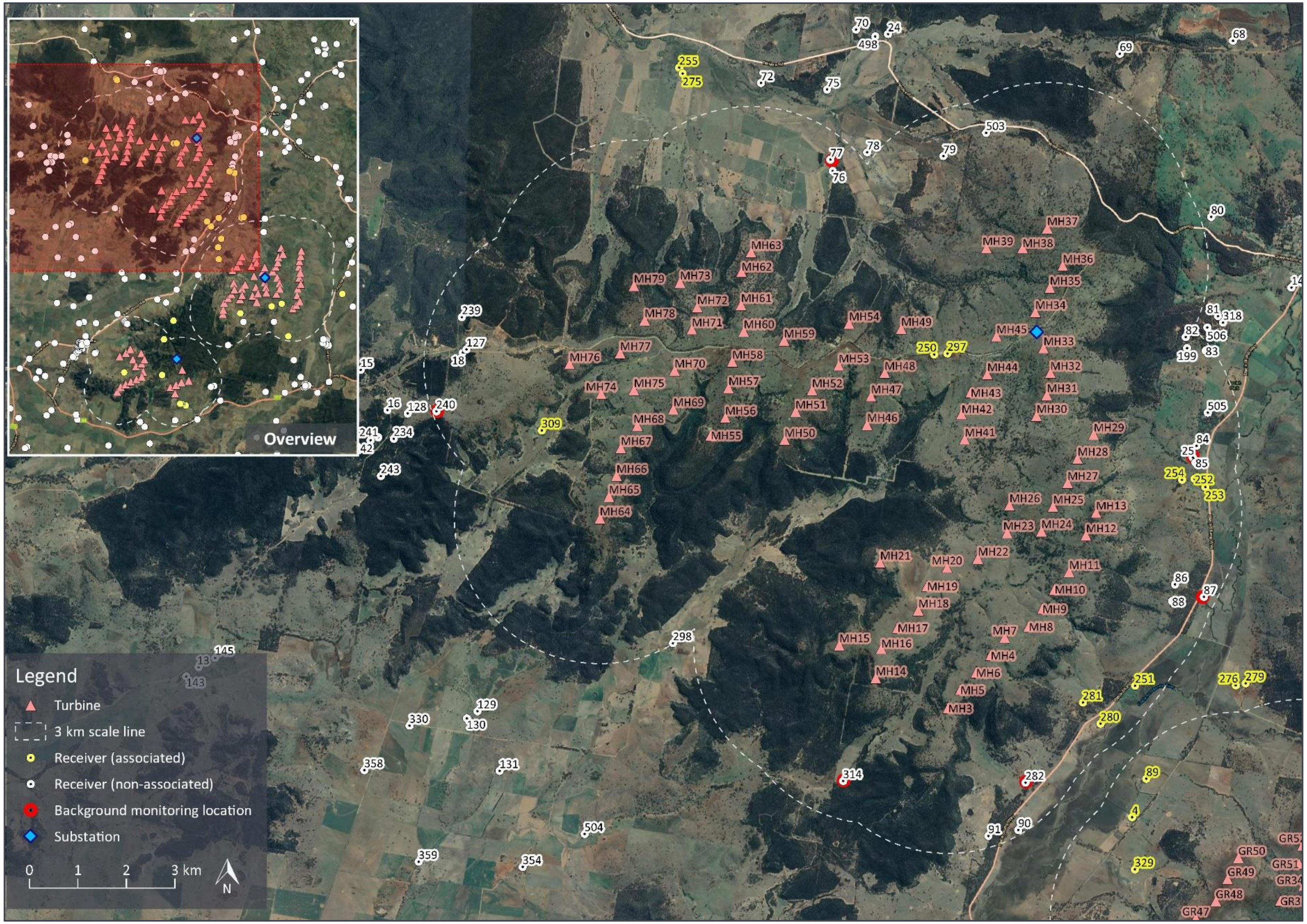


Figure 2: Site layout – Girragulang Road cluster

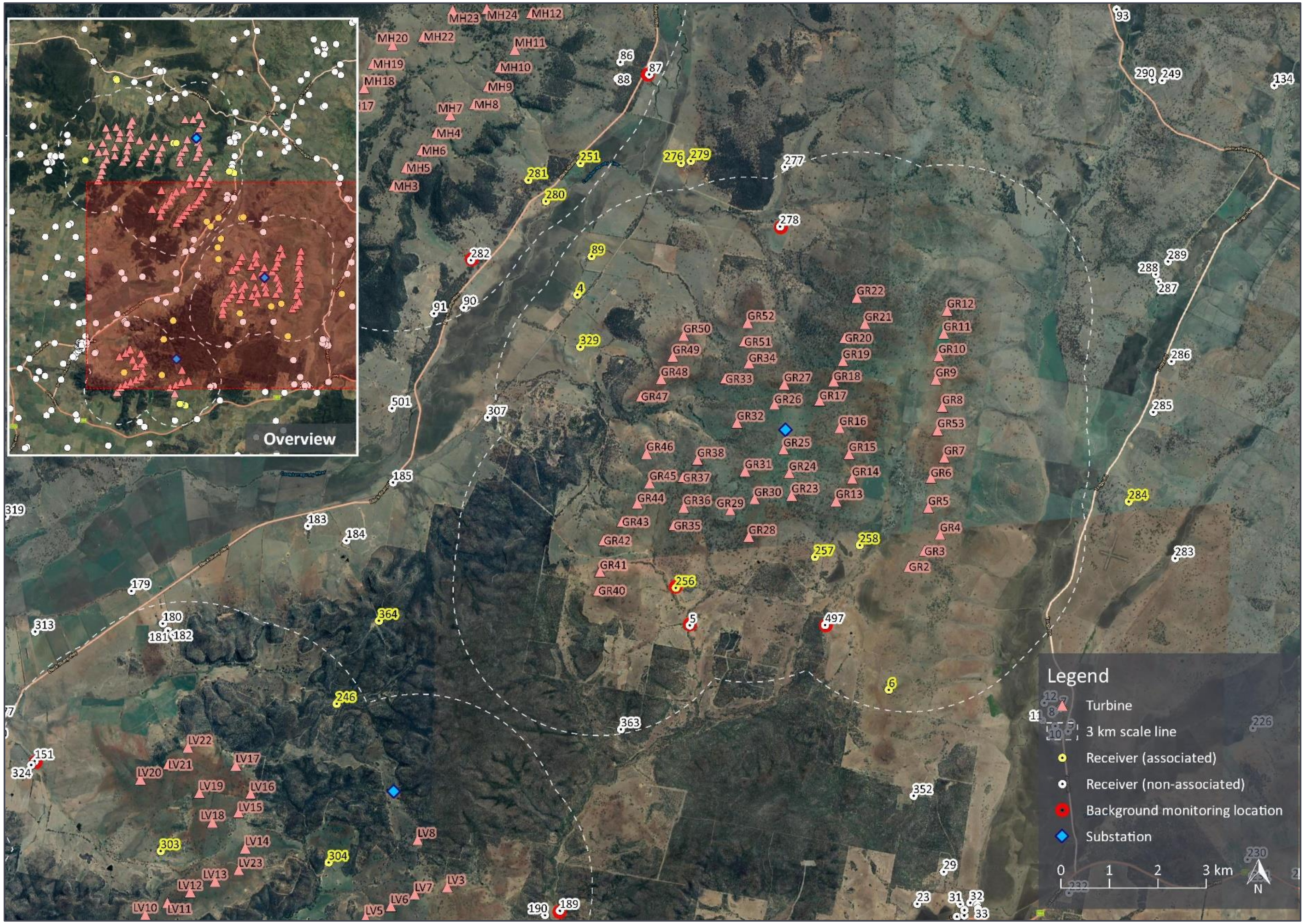
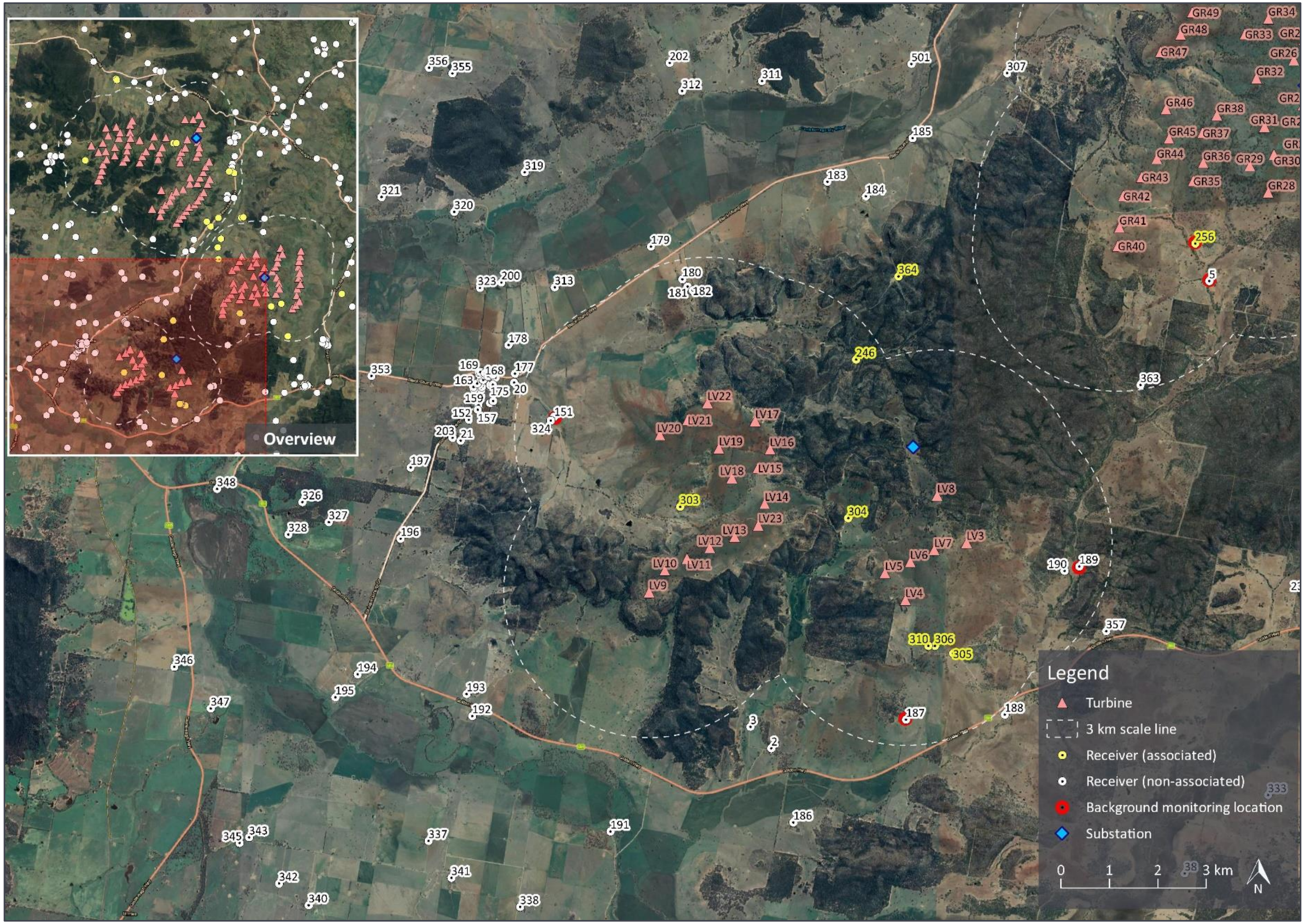


Figure 3: Site layout – Leadville cluster



2.0 NEW SOUTH WALES POLICY & GUIDELINES

Based on the requirements specified in the project SEARs, the following publications are relevant to the assessment of operational and construction noise from proposed wind farm developments in NSW:

- NSW DPE[4] publication *NSW Wind Energy: Noise Assessment Bulletin*, dated December 2016 (NSW Noise Assessment Bulletin);
- NSW EPA publication *Noise Policy for Industry*, dated 2017 (NPfI);
- NSW DECC[5] publication *Interim Construction Noise Guideline*, dated 2009 (ICNG);
- NSW DECCW[6] publication *NSW Road Noise Policy*, dated 2011 (RNP); and
- NSW DECC publication *Assessing Vibration: A Technical Guideline*, dated 2006 (AVTG).

Details of the guidance and noise criteria provided by these publications are provided in the following sections.

2.1 NSW Noise Assessment Bulletin

The NSW Noise Assessment Bulletin provides proponents of wind energy projects and the community with advice about how noise impacts are assessed for large-scale wind energy development projects that are a State significant development. The stated objective of the NSW Noise Assessment Bulletin is to ensure that the noise impacts of wind energy projects are appropriately identified, mitigated and managed.

The NSW Noise Assessment Bulletin specifies that the assessment of wind turbine noise is to be conducted in accordance with the South Australia EPA *Wind farms environmental noise guidelines*, dated July 2009 (SA Guideline), subject to a set of supplementary procedures that are specific to NSW. The variations relate to:

- *Noise limits:* selection of a lower base noise limit in all areas of NSW, in recognition that the regional areas of NSW with high quality wind resources are more populated than the equivalent regions in South Australia
- *Special noise characteristics:* definition of additional procedures and establishing low frequency as an assessable characteristic
- *Noise monitoring:* definition of additional technical procedures, including the use of alternative/intermediate noise monitoring locations for compliance monitoring.

The elements of the NSW Noise Assessment Bulletin that are applicable to the current planning stage assessment are described in further detail below.

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4 The former Department of Planning and Environment (DPE), now the Department of Planning, Industry and Environment (DPIE)

5 The former Department of Environment and Climate Change, now the DPIE

6 The former Department of Environment, Climate Change and Water, now the DPIE

2.1.1 Noise limits

In relation to noise limits, the variation defined in the NSW Noise Assessment Bulletin sets the base criterion at a value of 35 dB for all projects, in lieu of the 35 to 40 dB base criterion range defined in the SA Guideline. The criteria in the NSW Noise Assessment Bulletin are subsequently defined as follows:

> *The predicted equivalent noise level ($L_{Aeq,10 minute}$)*, adjusted for tonality and low frequency noise in accordance with these guidelines, should not exceed 35 dB(A) or the background noise ($L_{A90(10 minute)}$) by more than 5 dB(A), whichever is the greater, at all relevant receivers for wind speed from cut-in to rated power of the wind turbine generator and each integer wind speed in between.*
>
> ** Determined in accordance with SA 2009, Section 4.*

The NSW Noise Assessment Bulletin notes the following in relation to the types of receivers where the noise limits apply:

> *The criteria in this Bulletin have been developed to address potential noise impacts on the amenity of residents and other relevant receivers in the vicinity of a proposed wind energy project. Wind energy proponents commonly negotiate agreements with private land owners where applicable noise limits may not be achievable at relevant receiver locations. A negotiated agreement will be considered as part of the assessment of a wind energy project, as will the requirements of SA 2009 and this Bulletin. The proponent's EIS should clearly identify the expected noise levels at all receiver locations including host properties to ensure that affected persons are appropriately informed regarding the development proposal.*

Accordingly, the NSW Noise Assessment Bulletin noise limits only apply to non-associated receivers. Associated receivers are discussed in Section 2.1.4.

2.1.2 Tonality

Sounds which have unusually high levels of energy in a relatively narrow band of frequencies may be referred to as being tonal. Audible tonal sounds from wind turbines are generally related to rotational equipment in the turbine nacelle and can have a specific pitch dependent on the speed of rotation. This can cause the noise to be more annoying or noticeable. These tonal characteristics (as defined below) typically do not occur in well designed and well-maintained wind turbines.

The SA Guideline requires that development applications for wind energy projects report the following:

> *To help determine whether there is tonality, the method and results of testing (such as in accordance with IEC 61400–11) carried out on the proposed WTG model to determine the presence of tonality should also be specified in the development application.*

Section 4 of the SA Guideline further requires checks to be made during post completion compliance assessments.

Under the NSW Noise Assessment Bulletin, in addition to the above requirements, tonality is also assessed using the method described in Annex D of ISO 1996.2: 2007 *Acoustics - Description, measurement and assessment of environmental noise – Determination of environmental noise levels* for the assessment of tonality.

Tonality is defined as when the level of a one-third octave band (with the descriptor in accordance with the SA Guideline,) exceeds the level of the adjacent bands on both sides by:

- 5 dB or more if the centre frequency of the band containing the tone is in the range 500 Hz to 10,000 Hz;
- 8 dB or more if the centre frequency of the band containing the tone is in the range 160 Hz to 400 Hz; and/or
- 15 dB or more if the centre frequency of the band containing the tone is in the range 25 Hz to 125 Hz.

If tonality is found to be a repeated characteristic of the candidate wind turbine, 5 dB is to be added to the predicted or measured wind turbine noise levels. Note that 5 dB is the maximum penalty that may be applied for special noise characteristics, irrespective of whether one or more characteristics are present.

2.1.3 Low frequency noise

Low frequency noise is present in all types of environmental noise and is particularly difficult to measure in the presence of wind due to the increased level of background noise. The NSW Noise Assessment Bulletin indicates that low frequency noise is typically not a significant feature of modern wind turbine noise when it complies with the A-weighted noise limits.

In NSW, contemporary approvals include the following requirement for low frequency noise:

> *The presence of excessive low frequency noise that is a repeated characteristic* [i.e. noise from the wind farm that is repeatedly greater than 60 dB(C)] will incur a 5 dB(A) penalty, to be added to the measured noise level for the wind farm, unless a detailed low frequency noise assessment to the satisfaction of the Secretary demonstrates compliance with the proposed criteria for the assessment of low frequency noise disturbance (UK Department for Environment, Food and Rural Affairs (DEFRA, 2005)) for a steady state noise source.*
>
> ** The descriptor shall be in accordance with SA 2009, Section 4*

In the unlikely event that excessive low frequency noise is found to be a repeated characteristic of the wind turbine noise, 5 dB is to be added to the predicted or measured wind turbine noise levels. An assessment of C-weighted wind turbine noise levels must be undertaken against the 60 dB L_{Ceq} criteria at non-associated receivers in the vicinity of the wind farm. Note that 5 dB is the maximum penalty that may be applied for special noise characteristics, irrespective of whether one or more characteristics are present.

2.1.4 Associated receivers

The NSW Noise Assessment Bulletin also requires noise levels to be predicted for associated receivers, i.e. host properties and receivers where a noise agreement is in place with the proponent.

The SA Guideline provides guidance with respect to acceptable levels for *financial stakeholders,* presenting a base reference level of 45 dB L_{Aeq} for associated receivers, in order to provide context to the predicted noise levels for these locations.

Comparisons between the predicted noise levels and the 45 dB reference level are provided for informative purposes only. Noise levels at associated receivers will ultimately need to be managed in accordance with the commercial agreements established between the proponent and the landowners.

2.2 Noise Policy for Industry

The NPfI is the applicable guideline for assessing operational noise associated with the proposed related infrastructure i.e. the BESS and substations.

The NPfI provides a method for determining project noise trigger levels that are used for assessing the potential impact of noise from industry at existing receivers. Specifically, the project noise trigger levels provide a benchmark or objective for assessing a proposal or site. The NPfI states that the project noise trigger levels are not intended for use as mandatory requirements, but represent the levels that, if exceeded, would indicate a potential noise impact on the community, and so 'trigger' a management response; for example, further investigation of mitigation measures.

The project noise trigger levels are derived from an analysis of the background noise environment and zoning information, accounting for amenity-based criteria and, in the case of residential receivers, intrusiveness criteria. The project noise trigger levels are defined as the minimum of the intrusiveness noise levels and the amenity noise levels.

Assessments are conducted in terms of $L_{Aeq,\ 15\ min}$, as opposed to the $L_{Aeq,\ 10\ min}$ used for wind turbine noise assessments.

Additional criteria are defined for assessing the potential for sleep disturbance from noise sources that are characterised by transient events which result in brief periods of increased noise levels.

The following subsections describe the amenity and intrusiveness noise levels used to determine the project noise trigger levels. Further details on the derivation of appropriate project noise trigger levels for the assessment of operational noise levels from the related infrastructure are provided in Section 6.1.

2.2.1 Amenity noise levels

The amenity noise assessment is designed to prevent industrial noise continually increasing above an acceptable level. The NPfI provides recommended amenity noise levels based on receiver categories and typical planning zones.

The recommended amenity noise levels outlined in the NPfI have been selected on the basis of studies that relate industrial noise to annoyance in communities and have been subjectively scaled to reflect the perceived differential expectations and ambient noise environments of rural, suburban and urban communities for residential receivers. They are based on protecting the majority of the community (90 %) from being highly annoyed by industrial noise.

The amenity levels defined in the NPfI relate to total industry noise levels. The project amenity noise levels for an individual industry are set at a level 5 dB below the recommended amenity levels to provide a margin for cumulative industry noise.

2.2.2 Intrusiveness noise levels

The intrusiveness noise assessment is applicable to residential receivers and is based on knowledge of the background noise level at the receiver. The background noise levels are referred to as the rating background noise level (RBL) in the NPfI.

The intrusiveness noise level is the RBL at the nearest noise sensitive location plus 5 dB. Therefore, the noise emissions from the premises are considered to be intrusive if the source noise level ($L_{Aeq,\ 15\ min}$) is greater than the background noise level (L_{A90}) plus 5 dB.

2.3 Interim Construction Noise Guideline

The ICNG aims to provide a clear understanding of ways to identify and minimise noise from construction works through applying all 'feasible' and 'reasonable' work practices to control noise impacts. The guideline identifies sensitive land uses and recommends construction hours, provides quantitative and qualitative assessment methods and subsequently advises on appropriate work practices.

The ICNG recommended standard hours detailed in Table 1.

Table 1: Interim Construction Noise Guideline recommended standard hours of work

Work type	Recommended standard hours of work
Normal construction	Monday to Friday 0700 to 1800 hrs Saturdays 0800 to 1300 hrs No work on Sundays or public holidays
Blasting	Monday to Friday 0900 to 1700 hrs Saturday 0900 to 1300 hrs No blasting on Sundays or public holidays

The ICNG defines criteria in the form of management levels for both residential and non-residential receiver types.

In relation to residential receivers considered in this assessment, and based on the recommended standard hours, the ICNG provides two primary management levels for consideration in the assessment of noise at residential receivers:

- The noise affected management level is the NPfI's rating background noise level +10 dB; and
- The highly noise affected management level is prescriptively set at 75 dB $L_{Aeq,\ 15\ min}$.

Where noise from construction works is above the residential noise affected level, all feasible and reasonable work practices should be applied. Where the noise from construction works is above highly affected level for residential receivers, restrictions to the hours of construction may be required. The ICNG also defines the following five categories of works that might be undertaken outside the recommended standard hours are:

- the delivery of oversized plant or structures that police or other authorities determine require special arrangements to transport along public roads
- emergency work to avoid the loss of life or damage to property, or to prevent environmental harm
- maintenance and repair of public infrastructure where disruption to essential services and/or considerations of worker safety do not allow work within standard hours
- public infrastructure works that shorten the length of the project and are supported by the affected community
- works where a proponent demonstrates and justifies a need to operate outside the recommended standard hours.

The ICNG defines additional assessment and reporting requirements that apply if out of hours work is proposed, including justification of the need to work during these periods.

The ICNG also provides additional criteria for ground borne noise from construction vibration, applicable during the evening and night periods only. As construction is not expected to occur during these periods, ground borne noise is not considered in this assessment.

2.4 Road Noise Policy

The project SEARs indicates that additional traffic on public roads due to construction and operation of the wind farm must be assessed against the requirements of the NSW *Road Noise Policy* (RNP) and relevant application notes.

The RNP provides noise level criteria for increased traffic flow as a result of a land-use development with the potential to create additional traffic, as detailed in Table 2.

Table 2: Road traffic noise assessment criteria for residential land uses

Type of development	Day (0700-2200 hrs)	Night (2200-0700 hrs)
Existing residences affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments	60 dB $L_{Aeq, 15 hr}$ (external)	55 dB $L_{Aeq, 9 hr}$ (external)
Existing residences affected by additional traffic on existing local roads generated by land use developments	55 dB $L_{Aeq, 1 hr}$ (external)	50 dB $L_{Aeq, 1 hr}$ (external)

Additionally, the RNP requires that the relative increase in noise levels at residential receivers not exceed 12 dB for land use developments with the potential to generate additional traffic on existing freeways, arterial or sub-arterial roads. The relative increase criterion does not apply for local roads.

The RNP notes that in assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.

Where night-time construction traffic is likely to occur, an assessment of sleep disturbance is appropriate. The RNP provides guidance on this matter:

- Maximum internal noise levels below 50–55 dB LAmax are unlikely to awaken people from sleep
- One or two noise events per night, with maximum internal noise levels of 65–70 dB LAmax, are not likely to affect health and wellbeing significantly.

Based on the assumption that an open window provides 10 dB attenuation (which would be typical of a facade with partially open windows), noise levels below 60-65 dB LAmax outside an open bedroom window would be unlikely to cause awakening reactions.

Furthermore, one or two events with a noise level of 75-80 dB LAmax outside an open bedroom window would be unlikely to affect health and well-being significantly.

2.5 Assessing Vibration: A Technical Guideline

The project SEARs stipulate that vibration related to construction and operation of the proposed wind farm should be assessed in accordance with NSW DECC publication *Assessing Vibration: A Technical Guideline*, dated 2006 (AVTG).

The AVTG presents preferred and maximum vibration values for use in assessing human responses to vibration and provides recommendations for measurement and evaluation techniques. Preferred and maximum vibration values outlined in the AVTG are taken from British Standard 6472:1992 *Evaluation of human exposure to vibration in buildings (1-80 Hz)* (BS 6472).

The AVTG identifies three vibration categories:

- *Continuous vibration* – Examples: Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery)
- *Impulsive vibration* – Examples: Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading.
- *Intermittent vibration* – Examples: Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer this would be assessed against impulsive vibration criteria.

Similar to other policy and guideline documentation, the AVTG allows for assessment at various receiver types.

2.5.1 Intermittent vibration

The vibration characteristics of most construction activities (e.g. excavation and pilling) are considered to be intermittent. Intermittent vibration can be defined as interrupted periods of continuous vibration (e.g. heavy truck pass bys or rock breaking) or continuous periods of impulsive vibration (e.g. impact pile driving). Higher vibration levels are allowed for intermittent vibration compared with continuous vibration on the basis that the higher levels occur over a shorter time period. Hence, for intermittent vibration, human disturbance vibration levels are assessed on the basis of the Vibration Dose Value (VDV), based on the level and the duration of the vibration events. Vibration criteria applicable to residential receivers for intermittent vibration sources, are summarised in Table 3.

Table 3: Preferred and maximum vibration levels for human disturbance limits, VDV [2]

Assessment period [1]	Preferred value	Maximum value
Daytime	0.20	0.40
Night-time	0.13	0.26

Notes: 1 - Daytime is 0700 hr to 2200 hr and night-time is 2200 hr to 0700 hr

2 - These values are only indicative, and there may be a need to assess to other sensitive areas against the relevant criteria.

2.5.2 Continuous and impulsive vibration

Vibration criteria applicable to the residential receivers in the vicinity of the site for continuous vibration sources, are summarised in Table 4.

Table 4: Preferred and maximum vibration levels for human disturbance limits, m/s [2]

Vibration type	Assessment period [1]	Preferred values		Maximum values	
		Z axis	X and Y axes	Z axis	X and Y axes
Continuous vibration	Daytime	0.010	0.0071	0.020	0.014
	Night-time	0.007	0.005	0,014	0.010
Impulsive vibration	Daytime	0.30	0.21	0.60	0.42
	Night-time	0.10	0.071	0.20	0.14

Notes: 1 - Daytime is 0700 hr to 2200 hr and night-time is 2200 hr to 0700 hr
2 - The preferred and maximum values are weighted RMS acceleration values. These values are only indicative, and there may be a need to assess to other sensitive areas against the relevant criteria.

2.5.3 Blasting

Blast-induced vibration effects are assessed using the Australian and New Zealand Environment Council report *Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration*, dated September 1990 (ANZEC 1990 Report)

In its scope, the ANZEC 1990 Report provides the following context:

> *The recommended criteria apply only to the minimisation of annoyance and discomfort* [to persons at noise sensitive sites] *arising from blasting. The control of damage from blasting is the responsibility of State/Territory mines authorities and reference should be made to these bodies to ascertain recommended damage criteria.*
>
> *The recommended criteria are for guidance only and may be varied if necessary to suit local site conditions.*

The recommended criteria specified in the report are as follows:

- Airblast overpressure at sensitive sites should be:
  - below 115 dB L_{Zpeak} for 95 % of all blasts; and
  - below 120 dB L_{Zpeak} at all times.
- Ground vibration at sensitive sites should be:
  - below 5 mm/s (PPV) for 95 % of all blasts; and
  - below 10 mm/s (PPV) at all times.

From Australian and overseas research, damage (even of a cosmetic nature) has not been found to occur at airblast levels below 115 dB L_{Zpeak}. The probability of damage increases as the airblast levels increase above this level. Windows are the building element currently regarded as most sensitive to airblast, and damage to windows is considered as improbable below 140 dB L_{Zpeak}.

Based on the ANZEC 1990 Report , a limit of 115 dB L_{Zpeak} is referenced to practically minimise the risk of cosmetic or structural damage to typical residential constructions from airblast.

3.0 NOISE PREDICTION METHOD

3.1 Operational noise

Operational wind farm noise levels (wind turbines and related infrastructure) are predicted using:

- noise emission data for the wind turbines and related infrastructure;
- a 3D digital model of the site and the surrounding environment; and
- international standards used for the calculation of environmental sound propagation.

The method selected to predict noise levels is International Standard ISO 9613-2: 1996 *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation* (ISO 9613-2). The prediction method is consistent with the guidance provided by SA Guideline (referenced in the NSW Noise Assessment Bulletin) and has been shown to provide a reliable method of predicting the typical upper levels of the noise expected to occur in practice.

The method is generally applied in a comparable manner to both wind turbine and substation noise levels. For example, for both types of sources, equivalent ground and atmospheric conditions are used for the calculations. However, when applied to wind turbine noise, additional and specific input choices apply, as detailed below.

Key elements of the noise prediction method are summarised in Table 5. Further discussion of the method and the calculation choices is provided in Appendix F.

Table 5: Noise prediction elements

Detail	Description
Software	Proprietary noise modelling software SoundPLAN version 8.2
Method	International Standard ISO 9613-2:1996 *Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation* (ISO 9613-2). Adjustments to the ISO 9613-2 method are applied on the basis of the guidance contained in the UK Institute of Acoustics publication *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* (the UK Institute of Acoustics guidance). The adjustments are applied within the SoundPLAN modelling software and relate to the influence of terrain screening and ground effects on sound propagation. Specific details of adjustments are noted below and are discussed in Appendix F.
Source characterisation	Each source of operational noise is modelled as a point source of sound. The total sound of the component of the wind farm being modelled (i.e. the wind turbines or the related infrastructure) is then calculated on the basis of simultaneous operation of all elements (e.g. all wind turbines) and summing the contribution of each. To model the turbine components of the wind farm, the following specific procedures are noted: • Calculations of turbine to receiver distances and average sound propagation heights are made on the basis of the point source being located at the position of the hub of the turbine. • Calculations of terrain related screening are made on the basis of the point source being located at the maximum tip height of each turbine. Further discussion of terrain screening effects is provided below.
Terrain data	10 m resolution throughout the wind farm site provided by the proponent

Detail	Description
Terrain effects (turbine-specific procedures)	Adjustments for the effect of terrain are determined and applied on the basis of the UK Institute of Acoustics guidance and research outlined in Appendix F. Valley effects: +3 dB is applied to the calculated noise level of a wind turbine when a significant valley exists between the wind turbine and calculation point. A significant valley is determined to exist when the actual mean sound propagation height between the turbine and calculation point is 50 % greater than would occur if the ground were flat. Terrain screening effects: only calculated if the terrain blocks line of sight between the maximum tip height of the turbine and the calculation point. The value of the screening effect is limited to a maximum value of 2 dB. The project is located in a hilly area characterised by significant variations in ground elevation between the turbines and surrounding receivers. These terrain characteristics were sufficient to result in the application of adjustments to the predicted noise levels. Specifically, based on comparison of predicted noise levels with and without terrain elevation data included indicates terrain effects between -2 dB and +3 dB. For reference purposes, the ground elevations at the turbine and receivers are tabled in Appendix C and Appendix E respectively. The topography of the site is depicted in the elevation map provided in Appendix D.
Ground conditions	Ground factor of G = 0.5 on the basis of the UK IOA Good Practice Guide and research outlined in Appendix F. The ground around the site corresponds to acoustically soft conditions (G = 1) according to ISO 9613-2. The adopted value of G = 0.5 assumes that 50 % of the ground cover is acoustically hard (G = 0) to account for variations in ground porosity and provide a cautious representation of ground effects.
Atmospheric conditions	Temperature 10 ^{o}C and relative humidity 80 % These represent conditions which result in relatively low levels of atmospheric sound absorption and are chosen on the basis of the UK Institute of Acoustics guidance and the SA Guideline. The calculations are based on sound speed profiles[7] which increase the propagation of sound from each turbine to each receiver, whether as a result of thermal inversions or wind directed toward each calculation point. The primary consideration for wind farm noise assessment is wind speed and direction. The noise level at each calculation point is assessed on the basis of being simultaneously downwind of every wind turbine at the site. Other wind directions in which part or the entire wind farm is upwind of the receiver will result in lower noise levels. In some cases, it is not physically possible for a receiver to be simultaneously downwind of each turbine and the approach is therefore conservative in these instances.

[7] The sound speed profile defines the rate of change in the speed of sound with increasing height above ground

Detail	Description
Receiver heights	1.5 m above ground level It is noted that the UK Institute of Acoustics guidance refers to predictions made at receiver heights of 4 m. Predictions in Australia are generally based on a lower prediction height of 1.5 m which results in lower noise levels. However, importantly, predictions in Australia do not generally subtract a margin recommended by the UK Institute of Acoustics guidance to account for differences between L_{Aeq} and L_{A90} noise levels. The magnitude of these differences is comparable and therefore balance each other out to provide similar predicted noise levels. This approach has been shown to be valid for predicting noise level of wind farms expected to be measured using the L_{A90} parameter (as per the NSW Noise Assessment Bulletin).

3.2 Construction noise

Predicted noise levels have been calculated in general accordance with the method detailed in Australian Standard 2436:2010 *Guide to noise and vibration control on construction, demolition and maintenance sites* (AS 2436). This method enables the prediction of noise levels for sound propagation over hard or soft ground, but does not provide the ability to calculate predicted noise levels for mixed ground cover with varied soil conditions. The standard also notes that caution must be applied when considering predicted noise levels at distances beyond 100 m. For these reasons, predicted noise levels have been determined as the arithmetic average of the hard and soft ground prediction methods. This approach is broadly consistent with the equivalent prediction procedure in British Standard 5228-1:2009 *Code of practice for noise and vibration control on construction and open sites: Noise* (BS 5228, referenced in AS 2436), and provides a margin of caution with respect to ground conditions for the typical magnitude of separating distances between construction activities and neighbouring sensitive receivers.

4.0 EXISTING NOISE ENVIRONMENT

4.1 Policy

4.1.1 NSW Noise Assessment Bulletin

Background noise level information is used to inform the setting of noise limits for the assessment of wind turbine noise under the NSW Noise Assessment Bulletin. This is due to the need to consider the changes in background noise levels and wind turbine noise levels for different wind conditions.

The procedures for determining background noise levels for the assessment of wind turbines are defined in the SA Guideline, which is adopted by the NSW Noise Assessment Bulletin. Background noise levels are considered in terms of $L_{A90,\ 10\ min}$.

The first step in assessing background noise levels involves determining whether background noise measurements are warranted. For this purpose, Section 3.1 of the SA Guideline provides the following guidance:

> *Background noise measurements should be carried out at locations that are relevant for assessing the impact of WTG noise on nearby premises (relevant receivers).*
>
> *Relevant receiver locations are premises:*
>
> - *where someone resides or has development approval to build a residential dwelling;*
> - *where the predicted noise level exceeds the base noise level for the area [35 or 40 dB(A)] for wind speeds up to the speed of the rated power;*
> - *that are representative of the worst-case situation when considering the range of premises, e.g. a house located among a group of nearby houses within a residential zone.*

The initial stage of a background noise monitoring program in accordance with the SA Guideline therefore comprises:

- preliminary wind turbine noise predictions to identify all receivers where predicted noise levels are higher than 35 dB L_{Aeq}; and
- identification of selected receivers where background noise monitoring should be undertaken prior to the development of the wind farm, if required.

If required, the surveys involve measurements of background noise levels at receivers and simultaneous measurement of wind speeds at the site of the proposed wind farm. The survey typically extends over a period of several weeks to enable a range of wind speeds and directions to be measured. Data adversely affected by extraneous noise such as insect noise, rain and other considerations is filtered.

The results of the survey are then analysed to determine the trend between the background noise levels and the site wind speeds at the proposed hub height of the turbines. This trend defines the value of the background noise for the different wind speeds at which the turbines will operate. At the wind speeds when the value of the background noise is above 30 dB L_{A90}, the background noise levels are used to set the noise limits for the wind farm.

4.1.2 Noise Policy for Industry and Interim Construction Noise Guideline

Criteria applicable to related infrastructure noise and construction noise assessment also consider background noise levels measured on site.

Contrary to the descriptor used for background noise assessment under the NSW Noise Assessment Bulletin, background noise levels in the NPfI and ICNG, referred to as rating background noise levels, are assessed in terms of $L_{A90,\ 15\ min}$.

Measurement procedures for determining rating background noise levels are set out in Fact Sheet B *Measurement procedures for determining background noise* of the NpfI. Data developed for an NpfI assessment is also suitable for use as part of an assessment under the ICNG.

4.2 Background noise levels

4.2.1 NSW Noise Assessment Bulletin

Preliminary noise modelling of an earlier wind farm layout, summarised in MDA report Rp 001 20191254 *Valley of the Winds - Preliminary noise assessment*, dated 7 April 2020 (the preliminary noise report), indicated that background noise monitoring would be required to inform a detailed assessment in accordance with the NSW Noise Assessment Bulletin.

The background noise monitoring locations were proposed based on proximity to turbines, the location of receivers, and the predicted noise contours detailed in the preliminary noise report. Background noise monitoring was subsequently conducted at thirteen (13) receivers in the vicinity of the proposed wind farm between 1 June and 2 September 2021 equating to up to approximately 13 weeks at each location.

Analysis and results of the survey are detailed in MDA report Rp 002 20191254 *Valley of the Winds wind farm - Background Noise Assessment*, dated 23 February 2022 (background noise report).

Prior to the construction of the wind farm, background noise monitoring may be undertaken at additional receivers, should this be deemed appropriate.

A summary of background noise levels determined in accordance with the SA Guideline, as adopted by the NSW Noise Assessment Bulletin, are tabulated in Appendix G for the range of surveyed wind speeds. The results are illustrated in the graphical data provided for each receiver in the appendices of the background noise report.

4.2.2 Noise Policy for Industry and Interim Construction Noise Guideline

Review of measured background noise levels for the wind farm shows that L_{A90} noise levels during the day, evening and night periods are typically below 30 dB L_{A90} for extended periods at low wind speeds.

The NPfI recognises that very low background noise levels, particularly at night, can present challenges with the derivation of reasonable assessment criteria. Table 2.1 of the NPfI provides minimum assumed rating background noise levels which are summarised in Table 6.

These minimum levels are used for derivation of the NPfI project noise trigger levels in Section 6.1 and ICNG management levels in Section 8.0.

Table 6: Minimum assumed rating background noise levels for NPfI and ICNG, dB L_{A90}

Time of day	Minimum assumed RBL
Day	35
Evening	30
Night	30

Time of day is defined as:
- Day: 0700-1800 hrs Monday to Saturday and 0800-1800 hrs Sundays and public holidays
- Evening: 1800-2200 hrs Monday to Sunday and public holidays
- Night: the remaining periods

5.0 WIND TURBINE ASSESSMENT

5.1 Noise limits

5.1.1 Non-associated receivers

At non-associated receivers, the applicable noise limit in accordance with the NSW Noise Assessment Bulletin is 35 dB L_{A90} or background L_{A90} + 5 dB, whichever is higher.

Based on the background noise levels detailed in Table 6 of Section 4.1, applicable noise limits at the non-associated receivers where monitoring was undertaken are summarised in Appendix H.

5.1.2 Associated receivers

As detailed in Section 2.1.4, a base reference level of 45 dB L_{Aeq} is applied to all associated receivers. Comparisons between the predicted noise levels and the 45 dB reference level are provided for informative purposes only. Noise levels at these locations will ultimately need to be managed in accordance with the commercial agreements established between the proponent and the landowners.

5.2 Wind turbine model

The model of wind turbine ultimately selected for the project would be determined based on a range of design requirements.

Accordingly, to assess the proposed wind farm at this stage in the project, it is necessary to consider candidate turbine models that are representative of the size and type of turbines being considered. The purpose of the candidate turbine models is to assess the viability of achieving compliance with the applicable noise limits, based on noise emission levels that are typical of the size of turbines being considered for the site.

For this assessment, the proponent has considered the three (3) candidate turbine models detailed in Table 7.

The candidate turbine models are variable speed wind turbines, with the speed of rotation and the amount of power generated by the turbine being regulated by control systems that vary the pitch of the turbine blades (the angular orientation of the blade relative to its axis).

Table 7: Candidate wind turbine model specifications

Item	Details		
Model	SG 6.2-170	GE 6.0-164	V162-6.2 MW
Rated power, MW	6.2	6.0	6.2
Rotor diameter, m	170	164	162
Modelled hub height, m	119	119	119
Operating mode	AM0	N/A	PO6200
Serrated trailing edge	No	Yes	Yes
Highest sound power, dB L_{WA}	107.0	108.0	105.8

The proponent advised that the proposed candidate turbine models can operate at hub heights ranging from 119 m to 166 m. A sensitivity analysis demonstrated that a hub height of 119 m resulted in the highest predicted noise levels at receivers. As such, a hub height of 119 m has been used to assess wind turbine noise levels for all candidate turbine models. It is our understanding that the final hub height of the selected wind turbine model may differ slightly. However, the magnitude of the potential changes is not expected to alter the compliance outcome of the project.

5.3 Wind turbine noise emissions

5.3.1 Sound power levels

The noise emissions of the wind turbines are described in terms of the sound power level for different wind speeds. The sound *power* level is a measure of the total sound energy produced by each turbine and is distinct from the sound *pressure* level which depends on a range of factors such as the distance from the turbine.

Sound power level data for the candidate turbine models have been sourced from the following documents as provided by the proponent:

- Siemens Gamesa Renewable Energy document D2311679/006 *Standard Acoustic Emission AM0 - SG 6.2-170*, dated 29 July 2021
- GE Renewable Energy document 0082273 Rev: 2 *Technical Documentation Wind Turbine Generator Systems Cypress 6.0-164 - 50Hz - Product Acoustic Specifications According to IEC 61400-11*, dated 16 March 2021
- Vestas Power Solutions document 0105-5200_V00 *Third octave noise emission EnVentus™ V162-6.2 MW 50/60Hz*, dated 21 April 2021

Based on the data sourced from the above specification, the noise modelling conducted for this assessment involved conversion of third octave band levels to octave band levels and adjustment by addition of +1.0 dB at each wind speed to provide a margin for typical values of test uncertainty.

The overall A-weighted sound power levels (including the +1 dB addition) as a function of hub height wind speed are presented in Table 8 with the octave band values presented in Table 9.

Table 8: Sound power levels +1 dB uncertainty vs. hub height wind speed, dB L_{WA}

Model	Hub height wind speed, m/s									
	3	4	5	6	7	8	9	10	11	≥12
SG 6.2-170	93.0	93.0	95.5	99.4	102.8	105.7	107.0	107.0	107.0	107.0
GE 6.0-164	-	94.8	96.7	100.2	103.5	105.7	107.7	108.0	108.0	108.0
V162-6.2 MW	-	95.1	95.3	97.2	100.2	103.0	105.3	105.8	105.8	105.8

Table 9: Octave band sound power levels, dB L_{WA}

Model	Octave band centre frequency, Hz									
	31.5	63	125	250	500	1000	2000	4000	8000	Total
SG 6.2-170 [1]	-	87.8	95.7	98.1	97.6	101.0	101.8	97.0	85.8	107.0
GE 6.0-164 [2]	79.8	89.1	94.6	99.1	101.7	103.3	101.1	93.6	77.8	108.0
V162-6.2 MW [2]	76.7	87.1	94.6	99.2	100.9	99.8	95.7	88.8	79.0	105.8

Notes: 1- Based on one-third octave band levels at 9 m/s
2- Based on one-third octave band levels at 10 m/s

The values presented above are considered typical of the range of noise emissions associated with comparable multi-megawatt wind turbines.

A review of available sound power data for a range of turbine models has shown that there is no clear relationship between turbine size or power output and the noise emission characteristics of a given turbine model. In practice, the overall noise emissions of a turbine are dependent on a range of factors, including the turbine size and power output, and other important factors such as the blade design and rotational speed of the turbine. Therefore, while turbine sizes and power ratings of contemporary turbines have increased, the noise emissions of the turbines are comparable to, or lower than, previous generations of turbines as a result of design improvements (notably, measures to reduce the speed of rotation of the turbines, and enhanced blade design features such as serrations for noise control).

5.3.2 Tonality

Information concerning potential tonality is often limited at the planning stage of a project, and narrow band test data for tonality (in the form of IEC 61400-11 tonality data, as referenced in the SA Guideline) is presently unavailable for the candidate turbines. However, the occurrence of tonality in the noise of contemporary multi-megawatt turbine designs is unusual. This is supported by evidence of operational wind farms in Australia which indicates that the occurrence of tonality at receivers is atypical.

Further, the third octave band data detailed in the manufacturer's specification has been assessed against the additional tonality test prescribed in the NSW Noise Assessment Bulletin (detailed in Section 2.1.2). This test did not indicate the presence of tonality at any of the available hub height wind speeds for all the candidate turbine models.

On this basis, adjustments for tonality have not been applied to the predicted noise levels presented in this assessment. Notwithstanding this, the subject of tonality would be subject to further review and controls (i.e. contractual performance specifications) during the turbine procurement stage of the project, following approval of the wind farm, and again following the construction of the wind farm.

5.3.3 Low frequency noise

The NSW Noise Assessment Bulletin prescribes a criterion for the application of low frequency noise penalty adjustments, based on C-weighted noise levels. However, there is no established or verified engineering method for the prediction of C-weighted noise levels associated with the operation of wind turbines.

For the purposes of this report, a risk assessment approach has been adopted using a simplified prediction method to estimate the C-weighted noise levels for the GE 6.0-164 candidate turbine which has both the highest total sound power levels and the highest sound power levels at low frequencies (see frequency data in Section 5.3.1). Details of the assessment are provided in Appendix I.

The risk assessment indicates calculated low frequency noise levels are below the applicable thresholds for the application of penalties at all non-associated receivers. On the above basis, adjustments for low frequency noise have not been applied to the predicted noise levels presented in this assessment.

The effects of wind turbine noise on health and amenity are discussed in Appendix J.

5.4 Predicted noise levels

This section of the report presents the predicted A-weighted wind turbine noise levels at surrounding receivers, and an assessment of compliance with the applicable noise limits.

Sound levels in environmental assessment work are typically reported to the nearest integer to reflect the practical use of measurement and prediction data. However, in the case of wind farm layout design, significant layout modifications may only give rise to fractional changes in the predicted noise level. This is a result of the relatively large number of sources influencing the total predicted noise level, as well as the typical separating distances between the turbine locations and surrounding assessment positions. It is therefore necessary to consider the predicted noise levels at a finer resolution than can be perceived or measured in practice. It is for this reason that the levels presented in this section are reported to one decimal place.

The receivers where operational wind turbine noise levels are predicted to be higher than 30 dB L_{Aeq} are listed in Table 10 for non-associated receivers and Table 11 for associated receivers. The value of 30 dB is referenced here for informative purposes. The minimum wind turbine noise limit applicable at non-associated receivers is 35 dB L_{Aeq} as detailed in Section 5.1.1.

The predicted noise levels are for conditions when the wind turbine's noise emissions have reached their highest level (corresponding to hub height wind speeds of 9 m/s and above for the SG 6.2-170, and 10 m/s and above for the V162-6.2 MW and GE 6.0-164) and the wind is directed from the wind farm to each receiver.

The predicted noise levels include the +1 dB allowance to account for turbine sound power level measurement uncertainty, as described in Section 5.3.1.

Predicted noise levels for each integer wind speed are tabulated in Appendix K for all considered receivers, including those where the highest predicted noise level is below 30 dB L_{Aeq}.

Table 10: Highest predicted noise level at non-associated receivers with predicted levels above 30 dB L_{Aeq}, dB L_{Aeq}

Receiver	SG 6.2-170	GE 6.0-164	V162-6.2 MW
5	33.7	35.2	34.1
18	29.2	30.4	29.4
25	32.5	33.9	32.8
72	29.4	30.5	29.6
75	29.7	30.7	29.9
76	32.5	33.8	32.8
77	31.9	33.2	32.3
78	31.1	32.3	31.4
79	31.4	32.8	31.8
81	29.1	30.3	29.3
82	30.7	31.9	30.9
83	30.2	31.4	30.5
84	31.4	32.7	31.7
85	32.5	33.9	32.8
86	32.6	34.0	32.9
87	31.3	32.5	31.6
88	32.3	33.6	32.6
90	31.8	33.0	32.0
91	31.7	32.8	31.9
127	29.9	31.2	30.2
151	29.1	30.5	29.4
180	29.4	30.7	29.6
181	29.8	31.2	30.1
182	30.1	31.5	30.4
199	30.9	32.2	31.2
239	29.7	31.0	30.0
240	28.8	30.0	29.1
277	30.7	31.9	31.0
278	33.2	34.6	33.5
282	32.9	34.2	33.1
298	30.7	31.8	30.9
307	31.0	32.1	31.2

Receiver	SG 6.2-170	GE 6.0-164	V162-6.2 MW
314	31.3	32.5	31.5
318	29.3	30.5	29.5
324	29.3	30.7	29.6
497	33.2	34.6	33.6
501	29.4	30.3	29.4
503	29.1	30.4	29.3
505	30.6	31.9	30.9
506	30.3	31.5	30.5

Note: Values higher than 35 dB L_{Aeq} for non-associated receivers are greyed

It can be seen from Table 10 that the predicted wind turbine noise levels from the proposed wind farm are below the NSW Noise Assessment Bulletin base (minimum) criterion of 35 dB L_{Aeq} at all of the assessed non-associated receivers for two of the three candidate turbine models (SG 6.2-170 and V162-6.2 MW). The predicted noise levels for these candidate turbines are therefore below the derived limits presented in Section 5.1.1 for all wind speeds.

For the GE 6.0-164, the predicted wind turbine noise levels are below the base (minimum) criterion of 35 dB, and therefore below the derived criteria presented in Section 5.1.1, at all locations other than Receiver 5. At Receiver 5, the predicted noise level of the GE 6.0-164 reaches a maximum value of 35.2 dB, and an assessment of compliance requires consideration of the derived noise limits based on the background noise levels measured at the receiver. This comparison indicates the predicted noise levels of the GE 6.0-164 at Receiver 5 are below the derived noise limits at all wind speeds other than 10 m/s where a marginal excess of 0.2 dB is predicted.

The above findings support that the project can be designed and operated to comply with the operational noise requirements of the NSW Noise Assessment Bulletin.

Predicted noise levels at associated receivers are provided in Table 11 for information.

Table 11: Highest predicted noise level at associated receivers with predicted levels above 30 dB L_{Aeq}

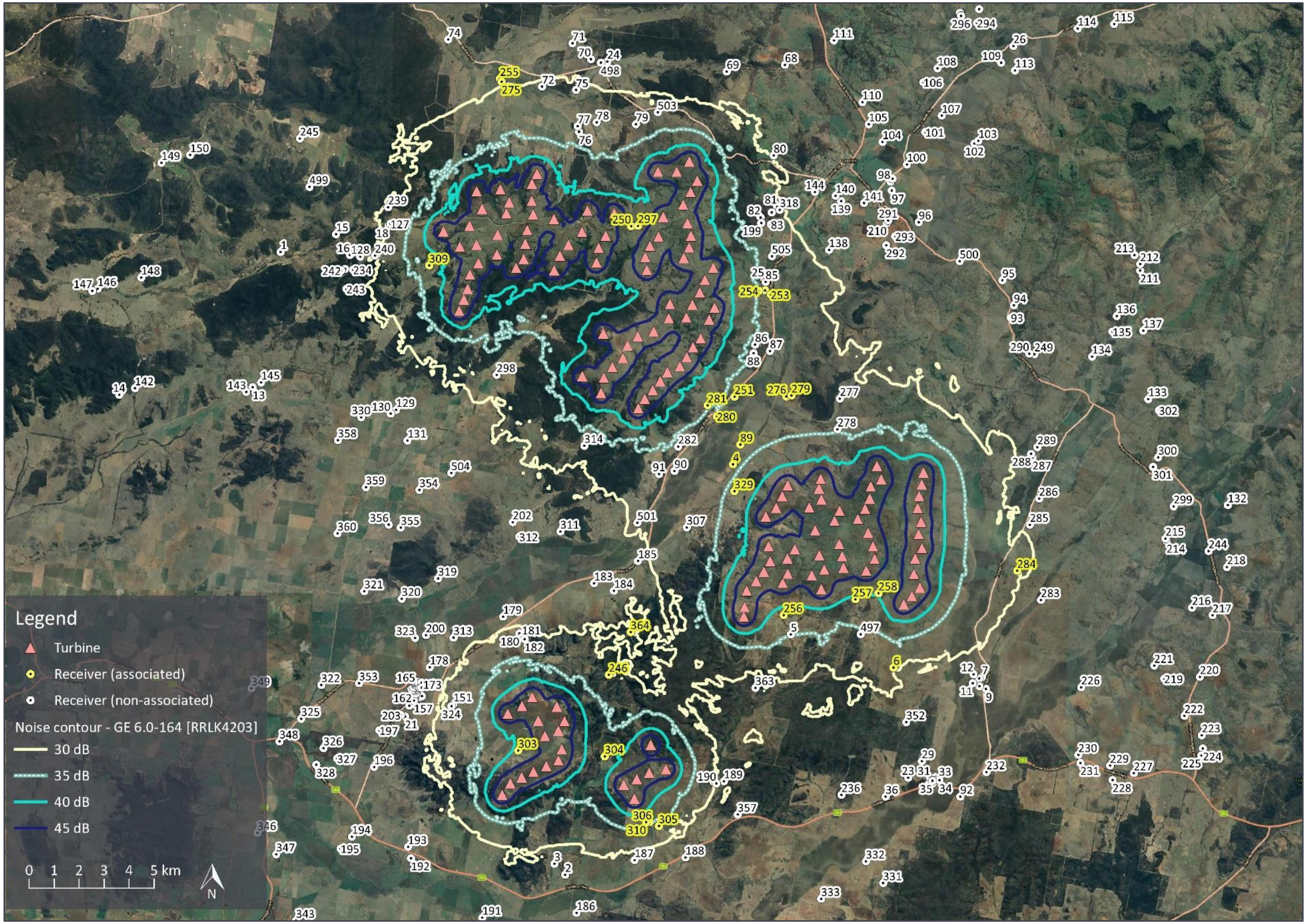
Receiver	SG 6.2-170	GE 6.0-164	V162-6.2 MW
4	32.9	34.2	33.2
6	30.9	32.1	31.1
89	32.6	33.8	32.9
246	29.2	30.5	29.5
250	41.1	42.8	41.3
251	32.7	34.0	33.0
252	32.7	34.1	33.0
253	32.1	33.5	32.4
254	33.0	34.5	33.3
256	36.7	38.4	37.0
257	37.7	39.3	38.0

Receiver	SG 6.2-170	GE 6.0-164	V162-6.2 MW
258	38.8	40.5	39.0
276	31.8	32.9	32.0
279	31.8	32.9	32.0
280	33.3	34.6	33.6
281	34.0	35.5	34.3
284	29.2	30.3	29.4
297	41.1	42.7	41.2
303	39.1	40.9	39.3
304	35.6	37.3	35.9
305	31.7	33.4	32.0
306	33.6	35.3	33.8
309	35.5	37.2	35.8
310	34.3	35.8	34.2
329	34.5	35.9	34.8
364	30.4	31.4	30.5

It can be seen from Table 11 that the predicted wind turbine noise levels from the proposed wind farm are below the reference level of 45 dB L_{Aeq} for all associated receivers.

The location of the total predicted 30 dB, 35 dB, 40 dB, and 45 dB L_{Aeq} noise contours for the candidate turbine model with the highest predicted noise levels (GE 6.0-164) is illustrated in Figure 4.

Figure 4: Highest predicted noise level contours for GE 6.0-164, dB L_{Aeq}



5.5 Cumulative assessment

The Liverpool Range Wind Farm (LRWF), located approximately 10 km northeast of the proposed Valley of the Winds wind farm (VoW) received development consent in March 2018 for approximately 267 wind turbines with a tip height of up to 165 m. However, a modification application has been submitted to reduce the total number of turbines, but enable an increased tip height of 239 m.

In relation to other wind farm developments, the NSW Noise Assessment Bulletin does not make specific recommendations concerning cumulative noise. The SA Guideline does however refer to cumulative noise, noting that the criteria have been specified to allow for other potential development and that any noise criteria which are set relative to background noise levels should not include the influence of other wind farms. While neither document explicitly states a requirement to assess the combined noise levels of multiple wind farm projects, nor do they define criteria that directly applies to cumulative noise, an assessment of cumulative noise from the project and the neighbouring LRWF is provided herein.

Preliminary noise modelling of an earlier wind farm layout, summarised in the preliminary noise report, included consideration of the nearby LRWF and presented predicted noise levels for the nearest LRWF turbines not exceeding 23 dB L_{Aeq} at any of the assessed receivers[8] in the vicinity of the VoW.

Noise levels around the LRWF have been predicted using the method detailed in Section 3.0 with the following additional key details:

- Turbine layout comprising 223 turbines provided by the proponent in a shapefile named *Liverpool_Range_Indicative_Wind_Turbine_Layout,* dated 14 December 2021;
- Candidate turbine model: GE 5.5-158[9];
- Turbine hub height: 160 m; and
- The overall A-weighted sound power levels[10] (including the +1 dB addition) as a function of hub height wind speed are presented in Table 12 with the octave band values presented in Table 13.

Table 12: Sound power levels versus hub height wind speed, dB L_{WA}

	Hub height wind speed, m/s								
Turbine	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**≥12**
GE 5.5-158	94.8	95.5	98.6	102.0	104.9	107.0	107.0	107.0	107.0

Table 13: Octave band sound power levels, dB L_{WA}

	Octave band centre frequency, Hz								
Turbine	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Total**
GE 5.5-158 [1]	79.0	88.2	93.6	98.2	100.7	102.3	100.1	92.7	77.0	107.0

Note: 1 Based on octave band levels at 9 m/s

8 Additional receivers have been considered in this assessment compared to the preliminary noise assessment

9 Accessed online: https://arcg.is/q9T9G on 14 December 2021

10 Sourced from MDA Report Rp 003 R01 20190463 *Delburn Wind Farm – Environmental noise assessment*, dated 26 January 2021 (weblink)

Cumulative operational noise requires consideration in two ways:

- The potential for the LRWF to influence noise levels at receivers near the VoW; and
- The potential for the VoW to influence noise levels at receivers near the LRWF.

As a visual guide to identify potential cumulative noise considerations, Figure 5 presents the predicted 25 dB L_{Aeq} contours of each project. The 25 dB value corresponds to a level that is 10 dB below the base noise criterion that applies to each project. The noise level contours relate to the separate contribution of each wind farm (i.e. rather than the cumulative predicted noise level from both wind farms).

As an indication of potential cumulative noise, predicted noise levels for the two projects are provided for the receivers where the predicted noise level of either wind farm is approaching the 35 dB L_{Aeq} base criterion which applies to each wind farm. Specifically, Table 14 and Table 15 present predicted cumulative noise levels for the receivers where predicted wind farm noise levels are higher than 32 dB L_{Aeq}[11] as a result of the VoW (using the GE 6.0-164 candidate turbine model) and the LRWF respectively.

The predicted noise levels presented in Table 14, Table 15 and Figure 5, are for the wind speeds which give rise to the highest noise emissions from each site respectively. It is also noted that the noise level contours are predicted on the basis of downwind propagation from each turbine; in most instances where cumulative noise is considered, a noise sensitive receiver cannot be simultaneously downwind of all wind turbines of adjoining projects. The predictions are therefore conservative[12] for the purpose of considering cumulative noise levels.

[11] The value of 32 dB L_{Aeq} was chosen as the minimum level that must occur from either project for there to be a possibly that the influence of the neighbouring wind farm could result in the total predicted noise level being higher than 35 dB L_{Aeq} base criterion which applies to each project.

[12] By a margin of up to 3 dB when compared to downwind predictions from each wind farm individually. This is distinct to variation of noise levels when a receiver is upwind of each wind farm when noise levels would be significantly lower than the downwind predictions.

Figure 5: Predicted 25 dB L_{Aeq} noise contour map for the Liverpool Range Wind Farm and Valley of the Winds wind farm

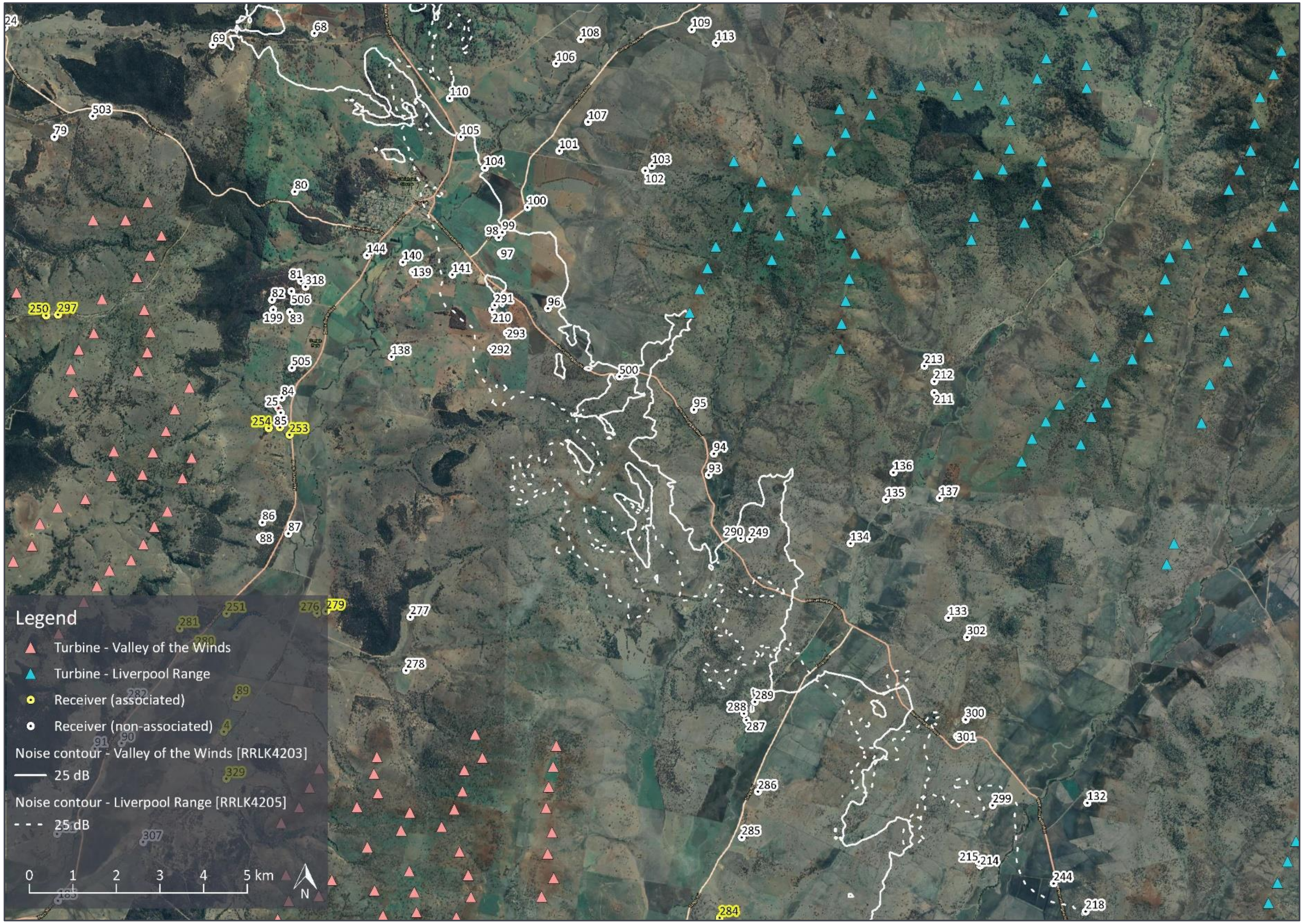


Table 14: Cumulative assessment for relevant VoW receivers, dB L_{Aeq}

Receiver	LRWF (GE 5.5 – 158)	VoW (GE 6.0-164)	Cumulative	Change in compliance outcome due to cumulative effects with respect to the base criterion
Non-associated receivers				
5	16.1	35.2	35.3	No
25	21.2	33.9	34.1	No
76	17.0	33.8	33.9	No
77	17.0	33.2	33.3	No
78	17.3	32.3	32.4	No
79	18.1	32.8	32.9	No
84	21.3	32.7	33.0	No
85	21.2	33.9	34.1	No
86	20.5	34.0	34.2	No
87	19.7	32.5	32.7	No
88	20.2	33.6	33.8	No
90	17.2	33.0	33.1	No
91	17.8	32.8	32.9	No
199	22.4	32.2	32.6	No
278	18.2	34.6	34.7	No
282	17.7	34.2	34.3	No
307	16.8	32.1	32.2	No
314	15.4	32.5	32.6	No
497	19.4	34.6	34.7	No
Associated receivers				
4	17.6	34.2	34.3	No
6	19.5	32.1	32.3	No
89	17.9	33.8	33.9	No
250	19.9	42.8	42.8	No
251	18.8	34.0	34.1	No
252	21.0	34.1	34.3	No
253	20.8	33.5	33.7	No
254	21.0	34.5	34.7	No
256	16.4	38.4	38.4	No
257	19.1	39.3	39.3	No

Receiver	LRWF (GE 5.5 – 158)	VoW (GE 6.0-164)	Cumulative	Change in compliance outcome due to cumulative effects with respect to the base criterion
258	18.5	40.5	40.5	No
276	17.7	32.9	33.0	No
279	17.9	32.9	33.0	No
280	18.3	34.6	34.7	No
281	18.3	35.5	35.6	No
297	19.6	42.7	42.7	No
303	10.2	40.9	40.9	No
304	11.8	37.3	37.3	No
305	11.9	33.4	33.4	No
306	11.8	35.3	35.3	No
309	13.7	37.2	37.2	No
310	11.8	35.8	35.8	No
329	17.0	35.9	36.0	No

Note: Values higher than 35 dB L_{Aeq} for non-associated receivers are greyed

It can be seen from Table 14 that the predicted noise levels from the LRWF are low (less than 23 dB L_{Aeq}) at receivers near to the VoW.

As a result, the change in predicted wind turbine noise levels attributable to the influence of the LRWF is up to 0.4 dB. For context, a 1 dB difference is generally not measurable or discernible in practice, particularly in the context of the much larger variations in ambient noise levels. The contribution of the LRWF does not result in a change of compliance outcome with respect to the 35 dB L_{Aeq} base criterion which applies to each wind farm. At Receiver 5, using the GE 6.0-164, the influence of the LRWF is predicted to increase the marginal excess at 10 m/s over the applicable criterion from 0.2 dB to 0.3 dB.

Table 15: Cumulative assessment for relevant LRWF receivers, dB L_{Aeq}

Receiver	LRWF (GE 5.5 – 158)	VoW (GE 6.0-164)	Cumulative	Change in compliance outcome due to cumulative effects with respect to the base criterion
Non-associated receivers				
102	32.8	23.5	33.3	No
103	33.5	23.6	33.9	No
113	32.1	20.8	32.4	No
114	34.4	18.4	34.5	No
115	36.0	17.3	36.1	No
117	34.6	17.0	34.7	No
118	34.9	16.7	35.0	No
119	35.2	17.3	35.3	No
198	36.2	18.3	36.3	No
204	37.7	15.6	37.7	No
205	37.8	15.6	37.8	No
211	34.3	18.5	34.4	No
212	34.3	18.4	34.4	No
213	34.8	18.6	34.9	No
263	32.2	14.9	32.3	No

It can be seen from Table 15 that the predicted noise levels from the VoW are low (less than 24 dB L_{Aeq}) at receivers near to the LRWF. As a result, the change in predicted noise level attributable to the influence of the VoW is not more than 0.5 dB; a difference that is not expected to be measurable or discernible in practice. The contribution of the VoW does not result in a change of compliance outcome with respect to the 35 dB L_{Aeq} base criterion which applies to each wind farm. Further, at the locations where the predicted noise level of the LRWF is higher than the 35 dB base criterion, the predicted noise level of the VoW is less than 20 dB and contributes 0.1 dB or less to the total predicted noise level; a negligible contribution in practice.

The assessment results demonstrate that cumulative noise considerations associated with the VoW can be practically managed, in terms of receivers near to both projects. In particular, the predicted increases in noise levels as a result of the cumulative influence of each project are small and not sufficient to result in an outcome change relative to the 35 dB L_{Aeq} base criterion which applies to each project.

6.0 RELATED INFRASTRUCTURE OPERATIONAL NOISE ASSESSMENT

6.1 Project noise trigger levels

For the purposes of this planning assessment, all receivers have been considered to be Rural in nature, as defined in Table 2.2 of the NPfI. On this basis, and considering the minimum assumed rating background levels detailed in Section 4.2.2, the project noise trigger levels for assessment of related infrastructure have been developed and are summarised in Table 16.

Table 16: NPfI project noise trigger levels, dB $L_{Aeq, 15 min}$

Time of day	Project noise trigger level
Day	40
Evening	35
Night	35

As the related infrastructure is proposed to operate on a 24 hour basis, the most stringent night-time noise level of 35 dB $L_{Aeq, 15 min}$ will be the controlling factor for compliance.

Further, the noise sources associated with the related infrastructure typically give rise to steady noise levels e.i. transformer noise, inverter and battery pack noise are not typically characterised by brief momentary increases in noise levels. Accordingly, the additional procedures defined in the NPfI for assessing potential sleep disturbance from brief elevated noise levels associated with transient noise sources are not relevant. The assessment is therefore primarily based on the equivalent noise levels of the plant.

6.2 Infrastructure noise sources

The proposed related infrastructure includes power transmission networks, three 250 MVA electrical substations, and battery energy storage system (BESS) components. The approximate coordinates used for the assessment of related infrastructure noise are detailed in Table 17.

Table 17: Approximate related infrastructure coordinates (GDA 2020 zone 55)

Infrastructure item	Easting, m	Northing, m
Mount Hope substation	751,138	6,473,835
Girragulang Road substation	757,396	6,461,039
Leadville substation	749,320	6,453,585

At this stage in the project, specific details of the transformer make and model are yet to be determined. However, to provide a basis for assessing the feasibility of the proposed terminal station, the proponent advised that a single transformer rated to 250 MVA is proposed for each of the three (3) substations.

In lieu of measured sound power level data for a specific transformer selection, reference has been made to Australian Standard AS 60076-10:2009 *Power transformers – Part 10: Determination of sound levels* (AS 60076-10:2009) which provides a method for estimating transformer sound power levels. Specifically, Figure ZA1 from AS 60076-10:2009 has been used to determine an estimated standard maximum sound power level of 100 dB L_{WA}.

Similarly, BESS equipment details are not known at this stage however total equipment sound power levels from other similar projects are within the range of 95-100 dB L_{WA}. For the purposes of this assessment, the sound power levels shown in Table 18 have been used.

Table 18: Ancillary infrastructure sound power levels, dB L_{WA}

Infrastructure item	Source	Sound power level
Mount Hope substation	250 MVA transformer	100
Girragulang Road substation	250 MVA transformer	100
	BESS	98
Leadville substation	250 MVA transformer	100

6.3 Predicted noise levels

Noise levels have been predicted at the nearest non-associated and associated receivers based on the method detailed in Section 1.

As equipment selections are not known, the tonality characteristics of the transformers cannot be anticipated. In order to provide a conservative assessment an adjustment of +5 dB (as per the NPfI) has been applied to the predicted noise levels to account for the potential tonal characteristics of transformer noise.

Predicted noise levels at the nearest non-associated and associated receivers are shown in Table 19 and Table 20, respectively.

Table 19: Predicted noise levels at the nearest non-associated receivers (including +5 dB tonality penalty), dB L_{Aeq}

Infrastructure item	Nearest non-associated receiver	Distance, m	L_{Aeq}
Mount Hope substation	82	3,074	<15
Girragulang Road substation	497	4,107	<15
Leadville substation	190	4,034	<15

Table 20: Predicted noise levels at the nearest associated receivers (including +5 dB tonality penalty), dB L_{Aeq}

Infrastructure item	Nearest associated receiver	Distance, m	L_{Aeq}
Mount Hope substation	297	1,893	21
Girragulang Road substation	257	2,694	19
Leadville substation	304	1,988	20

While the specific equipment selections would not be finalised until the detailed design phase of the project, noise levels from the transformers and BESS equipment are predicted to be substantially below the 35 dB L_{Aeq} night-time project noise trigger level applicable at the nearest non-associated and associated receivers.

Noise from the ancillary electrical infrastructure is therefore predicted to be below the most stringent applicable noise level criteria, even accounting for any adjustments (if applicable at the receptor) for the potential tonal characteristics associated with transformers.

7.0 RECOMMENDED OPERATIONAL NOISE MANAGEMENT MEASURES

In order to ensure that operational noise from the wind farm is appropriately managed during subsequent stages of the development, the following is recommended:

- The predicted operational wind turbine noise levels should be updated with final layout and sound power levels of the final turbine selected for the site to verify compliance with the criteria in accordance with the NSW Assessment Bulletin;
- The predicted operational related infrastructure noise levels should be updated with the final design and sound power levels of the final equipment selection to verify compliance with the criteria in accordance with the NPfI;
- A noise management plan should be prepared which identifies how compliance with the wind farm's operational noise limits will be demonstrated, including details of testing procedures and reporting time frames following commencing of operation of the wind farm; and
- Following construction, compliance monitoring must be conducted to satisfy the NSW Noise Assessment Bulletin including evaluation of special noise characteristics.

In addressing SEARs, and assessing operational wind turbine noise in accordance with the NSW Noise Assessment Bulletin, it is expected that the project will satisfy the applicable noise limits. Notwithstanding this, consideration has been given to available contingency strategies to reduce noise levels if required.

The following summarises the two key measures available to reduce the noise:

- Procurement contract: the procurement contract for the supply of turbines to the site will typically include specifications concerning the allowable total noise emissions from the turbine, and the permissible characteristics of the turbine. In the event that turbine emissions are found to exceed the contracted values, the supplier will be required to implement measures to reduce the noise to the contracted value. This can include measures to rectify manufacturing defects or appropriate control settings.
- Noise reduction management strategy: modern wind farms include control systems which enable the operation of the turbines to be varied according to environmental constraints. Specifically, variable pitch turbines as proposed for this site include control functions which enable the noise emissions of the turbines to be selectively controlled; by adjusting the pitch of blade, the noise emissions of the turbine can be reduced. In addition, where required, the turbines can be selectively shut down under relevant wind speeds and directions. These types of control measures can be used separately, or in combination, to achieve noise reductions for predetermined wind speed ranges and directions.

8.0 CONSTRUCTION NOISE AND VIBRATION ASSESSMENT

8.1 Overview

The construction of a wind farm project will generate noise and vibration as a result of activities occurring both on and off the site of the proposed development. As per the SEARs, construction noise is to be assessed in accordance with the ICNG and construction vibration in accordance with the AVTG (see Section 2.0).

Off-site noise generating activities primarily relate to heavy goods vehicle movements to and from the site and is addressed in the traffic noise assessment in Section 9.0.

On-site works include a range of activities such as construction of access tracks, connection infrastructure, gravel quarry, turbine foundations and erection of the turbines.

Construction of a wind farm mostly occurs at relatively large separating distances from receivers and, as proposed for this project, the majority of the work is limited to normal working hours. The only exceptions are for potential unavoidable works or low-noise managed-works. Unavoidable works outside of normal hours are expected to comprise the delivery of oversized turbine components at times selected to minimise traffic disruption associated with intersection closures, and potentially turbine installation activities that are sensitive to weather conditions (e.g. installation of rotors or concrete pouring during summer).

As per the ICNG, noise associated with the construction of a wind farm may require the adoption of reasonable and feasible general management measures and considerate working practices. These measures are normally documented and agreed in a Construction Noise and Vibration Management Plan (CNVMP) for inclusion in a broader Environmental Management Plan (EMP), which is typically prepared for review and approval by the responsible authority prior to commencing any construction works.

The following sections provide general information regarding the types of activities that are expected to be associated with the construction of the wind farm, and reference data that should be considered as part of the preparation of a future CNVMP for the project.

8.2 Construction activities

Construction of a wind farm project typically involves the following key stages:

- Access road construction
- Cable trench digging
- Concrete batching plant
- Site compound construction
- Substation construction
- BESS construction
- Turbine foundations
- Turbine assembly
- Gravel quarry

Specific details of the construction program and the number, type and duty of the construction plant to be used would be determined during the advanced stages of a wind farm project when a construction contractor has been selected.

The types of equipment associated at different stages of construction typically include excavation plant, pneumatic equipment and lifting equipment.

Appendix L provides a construction site layout denoting key work areas. Appendix M details typical major equipment items associated with the above construction stages, alongside noise levels developed on the basis of reference data from AS 2436 and previous project experience.

As shown in Appendix M, typical construction plant sound power levels range from approximately 100-120 dB L_{WA} per equipment item.

Based on the groupings of major plant items during key construction tasks, the total aggregated noise emissions of for the stages typically ranges from 115 to 125 dB L_{WA}.

8.3 Construction noise assessment

Noise levels associated with each of the main construction tasks have been predicted at the nearest noise sensitive receivers to provide an indication of the upper range of noise levels.

Given that the precise equipment selections and methods of working would be determined during the future development of a CNVMP, and that the noise associated with construction plant and activity varies significantly, the predicted noise levels are provided in the following sections as an indicative range of levels which may occur in practice.

Table 21 details the predicted noise level ranges for each of the main construction tasks at the nearest non-associated and associated receivers.

Table 21: Indicative range of construction noise predictions, dB L_{Aeq}

Construction task	Nearest receiver	Predicted level range	Noise affected management level	Exceedance	Highly noise affected management level	Exceedance
Non-associated receivers						
Access road construction	31	80-85	45	35-40	75	5-10
Cable trench digging	5	35-40	45	-	75	-
Concrete batching plant	497	40-45	45	-	75	-
Site compound construction	497	45-50	45	0-5	75	-
Substation construction	82	30-35	45	-	75	-
BESS construction	497	25-30	45	-	75	-
Turbine foundations	5	35-40	45	-	75	-
Turbine assembly	5	35-40	45	-	75	-
Gravel quarry	182	40-45	45	-	75	-
Associated receivers						
Access road construction	297	70-75	45	25-30	75	-
Cable trench digging	297	70-75	45	25-30	75	-
Concrete batching plant	6	40-45	45	-	75	-
Site compound construction	6	45-50	45	0-5	75	-
Substation construction	297	35-40	45	-	75	-
BESS construction	257	30-35	45	-	75	-
Turbine foundations	250	45-50	45	0-5	75	-
Turbine assembly	250	45-50	45	0-5	75	-
Gravel quarry	303	40-45	45	-	75	-

The predicted noise levels presented in Table 21 indicate the highly noise affected management levels are expected to be exceeded at some of the nearest non-associated receivers, generally located at the entrance of access roads to each wind farm cluster, during the construction of access roads. However, the predicted noise levels indicate that noise affected management levels are anticipated to be exceeded at some of the nearest non-associated receivers during the construction of access roads and the site compound.

For associated receivers, the noise affected management levels at some of the nearest receivers are expected to be exceeded during most construction stages. However, predicted noise levels during all construction stages are expected to be below highly noise affected management levels at all of the nearest associated receivers.

Exceedances above the highly noise-affected and noise affected management levels are not unique to this project and are characteristic of most construction assessments due to the typically high source noise levels of construction equipment. Based on previous project experience the predicted noise levels are typical of the range expected for the construction of a wind farm.

Due to the proximity of the subject receivers to the subject sources, the highest predicted noise levels are noted to occur during the construction of access roads cable trench digging activities.

8.3.1 Discussion – Access road construction

The construction activity that would typically occur nearest to receivers is the construction of access roads.

This activity involves a brief period of elevated noise while work is carried out to improve existing roads (where required), create new intersections at site access points, and initiate site access tracks.

During these initial works, construction noise levels of the order of 70-75 dB L_{Aeq} could be expected for brief periods when road and access work is carried out at distances within 60 m from a receiver.

It is expected that during site access works, only two (2) non-associated receivers and no associated receiver would be located less than 60 m from this type of construction activities. It is also noted that most of the non-associated receivers within 500 m of the access road construction activities are located within the intersection of the main roads (Golden Highway and Black Stump Way) and the proposed access roads.

For context, the predicted noise levels are comparable to, and typical of, noise levels produced by general road maintenance works and activity.

8.3.2 Discussion – Cable trench digging

Similar to the construction of access roads, cable trench digging activities will generally move along the intended routes reasonably quickly, with activities moving throughout the project site. On this basis trench digging activities are unlikely to be a feature of any one receiver for an extended period of time.

During these initial works, construction noise levels of the order of 70-75 dB L_{Aeq} could be expected for brief periods when road and access work is carried out at distances within 60 m from a receiver.

It is expected that during this stage of works, only one (1) associated receiver and no non-associated receivers would be located less than 60 m from this type of construction activities.

8.3.3 Discussion – General

The majority of the remainder of construction activities occurs in proximity to the turbine locations and related infrastructure locations. These works therefore typically occur at larger separating distances from receivers. As a result, construction noise levels are then lower. However, depending on background noise levels and wind directions, construction noise associated with more distant works would still be audible at surrounding receivers at times. In particular, given the low background noise levels that occur in rural environments at low wind speeds, construction noise could be higher than background noise levels on some occasions.

The ICNG indicates:

The noise affected level represents the point above which there may be some community reaction to noise.

- *Where the predicted or measured $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level.*
- *The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.*

The predicted noise levels summarised in Table 21 indicate that highly noise affected management levels are expected to be exceeded by up to 10 dB at some receivers, generally located within the intersection of the main roads (Golden Highway and Black Stump Way) and the proposed access roads, during the construction of access roads.

The IGNG provides additional comments with respect to highly noise affected management levels:

The highly noise affected level represents the point above which there may be strong community reaction to noise.

- *Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account:*

  1. times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences

  2. if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.

Therefore, community consultation and negotiation of respite periods should be considered during a future detailed CNVMP.

8.4 Construction vibration assessment

The prediction of vibration propagation through the ground is considered convoluted and complex, and depends on several factors including damping, reflection and impedance in-ground conditions. A detailed vibration propagation assessment is considered to be a site-specific assessment and often requires a combination of baseline vibration assessment, empirical measurement of equipment and analytical methods. Assessment of this nature is outside of the scope of a planning stage vibration risk assessment.

The AVTG provides guidance with respect to the assessment of human comfort due to vibration from construction works. This guideline provides distinguishes intermittent, impulsive and continuous vibration sources, which can be generated by construction activities. For the purposes of this planning risk assessment only residential receivers are considered.

8.4.1 Intermittent vibration

The AVTG indicates that intermittent vibration should be assessed in terms of the Vibration Dose Value (VDV). These values for intermittent construction activities are highly specific to site conditions, equipment selections and operational durations. As such, calculation of VDV levels is not typical or practical at the planning stage but will need to be considered as part of a later detailed vibration assessment.

The AVTG recommends that best management practices in all cases should be to reduce values as far as practicable, and a comprehensive community consultation program should be developed.

8.4.2 Continuous vibration

Vibration due to some construction operations can be considered continuous depending on the duration and nature of the works. Since the guide values for continuous vibration are independent of exposure duration, indicative safe working distances can be developed. Section 7.1 of the NSW RMS[13] *Construction Noise & Vibration Guideline* (CNVG) sets out minimum working distances from sensitive receivers for typical items of vibration intensive plant. The minimum distances, reproduced in Table 22, are quoted for effects relating to human comfort.

Table 22: Recommended minimum working distances for human response limits for vibration intensive plant at nearest receivers

Plant item	Rating / description	Minimum working distance, m
Vibratory roller	< 50 kN (typically 1-2 tonnes)	15 to 20
	< 100 kN (typically 2-4 tonnes)	20
	< 200 kN (typically 4-6 tonnes)	40
	< 300 kN (typically 7-13 tonnes)	100
	> 300 kN (typically 13-18 tonnes)	100
	> 300 kN (> 18 tonnes)	100
Small hydraulic hammer	(300 kg – 5 to 12 t excavator)	7
Medium hydraulic hammer	(900 kg – 12 to 18 t excavator)	23
Large hydraulic hammer	(1600 kg – 18 to 34 t excavator)	73
Vibratory pile driver	Sheet piles	20
Pile boring	≤ 800 mm	4
Jackhammer	Handheld	2

Note: Reproduced from Table 2 of Section 7.1 of the CNVG

The CNVG notes that the minimum working distances for human comfort relate to continuous vibration and are indicative. In practice, appropriate minimum working distances will vary depending on the particular item of plant and local geotechnical conditions. The CNVG further notes that for most construction activities, vibration emissions are intermittent in nature and for this reason, higher vibration levels, occurring over shorter periods are allowed, likely equating to greater minimum working distances.

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8.4.3 Blasting

It is our understanding that blasting is likely to be required as part of the quarry operations. The excavation methods that will be needed in order to prepare the foundations of the turbines and other on-site infrastructure are yet to be determined. However, it is our understanding that low level blasting could potentially be required in some instances.

The accurate estimation of airblast and ground vibration is complex and subject to considerable uncertainty. The blasting process is highly non-linear and the variability of ground and rock also contributes to the difficulty in accurate predictions.

As the need for blasting is yet to be determined, it is not possible provide an estimate of potential airblast and ground vibration levels. However, in the event that blasting is ultimately required, the activities would need to be addressed in a blasting plan which sets out the management and monitoring measures to be implemented, including identification of the locations where blasting could be conducted, if required, in accordance with the ANZEC 1990 Report.

Once further information is known it may be feasible to establish general indications of airblast overpressure and ground vibration levels at the nearest receivers to the proposed blasting areas, by undertaking a high-level assessment in accordance with AS 2187-2:2006 *Explosives—Storage, transport and use, Part 2: Use of explosives* (AS 2187-2).

8.5 Construction workforce accommodation facility

It is proposed to construct a workers accommodation camp for 400 people, approximately 3 km west of the Girragulang Road cluster, near to Receiver 307, as shown in Appendix L.

Considering the separation distance between the proposed accommodation facility and construction activities, the noise and vibration impact at this location is considered to be negligeable.

8.6 Decommissioning

Similar construction activities to those detailed in Section 8.2 are expected to be required during the decommissioning of the project. As such, noise impacts associated with the decommissioning of the project are expected to be similar in nature to those experienced during construction.

8.7 Construction noise and vibration recommendations

At this early stage only a preliminary assessment of construction noise and vibration impact risk is feasible. Once a more detailed schedule of equipment and plant items, construction method and work areas are known, a detailed CNVMP should be prepared.

Any future CNVMP should include site and process specific noise management work practices designed to mitigate the impact of construction noise activities, including traffic noise and blasting.

The ICNG provides extensive details and guidance with respect to noise mitigation including:

- Universal work practices
- Consultation and notification
- Plant and equipment
- On-site controls
- Work scheduling
- Transmission path and at-receiver considerations

All of the above items should be considered as part of the future CNVMP.

Generally, it is likely to be feasible for a majority of works to be restricted to normal working hours, i.e. the ICNG recommended standard construction hours detailed in Section 2.3. This will assist in limiting noisy activities to times of the day when intrusive impacts or adverse reactions may be less likely.

In some cases, construction works may be required to occur outside of these hours. Such activities are typically related to public infrastructure i.e. timing oversized deliveries to avoid hazardous traffic conditions or weather windows, i.e. aspects of turbine assembly which must occur in still wind conditions for safety reasons.

Where out of hours works are proposed, the ICNG advises:

- *A strong justification would typically be required for works outside the recommended standard hours.*
- *The proponent should apply all feasible and reasonable work practices to meet the noise affected level.*
- *Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community.*

General experience of wind farm developments has indicated that construction noise tends to represent a limited risk factor. With reasonable and feasible work practices implemented, and considering that the Highly noise affected management levels are not predicted to only exceeded at a few receivers during the construction of access roads cable trench digging activities, it is expected that noise associated with the construction and decommissioning of the wind farm can be acceptably managed.

9.0 TRAFFIC NOISE ASSESSMENT

Noise criteria for the assessment of traffic associated with the construction and operation of the wind farm are laid out in Section 2.4.

The traffic report[14] indicates that traffic generation during operational stages is limited, with construction stage traffic likely to comprise the majority of traffic associated with the development,

Operational traffic impacts on public roads are likely be very low and have negligible noise impacts and are not considered further in this report.

Construction traffic flows on public roads is detailed in Section 5.1 of the traffic report and reproduced below.

Table 23: Construction traffic and base traffic flows on public roads

Existing daily traffic volume category	Applicable roads	Future year base daily traffic volume (2023)	Additional construction daily traffic volume	Future year with construction daily traffic volume category	Upgrade needed (Y/N?)
1-150	Short Street GH Turee Street GH Main Street GH Wyaldra Street GH Moorefield Road (east) GH	<100	344	150-500	Y
	Moorefield Road (west) GH	<50	210	150-500	Y
	Wardens Road LV	<50	210	150-500	Y
	Garland Street LV	<50	210	150-500	Y
	Mount Hope Road MH	<50	244	150-500	Y
150-500	Neilrex Road MH	<200	244	150-500	N
	Queensborough Street MH	<250	244	150-500	N
1,000-3,000	Black Stump Way MH	<400	334	1,000-3,000	N

Notes: GR Girragulang Road cluster
MH Mount Hope cluster
LV Leadville cluster

The traffic volumes are very low in absolute levels and the Calculation of Road Traffic Noise (CoRTN) prediction method, preferred by Transport for NSW and the EPA, is not typically applied where traffic flows are less than 50 vehicles per hour. A correction factor for low traffic volumes, where less than 200 vehicles per hour has been applied in accordance with the CoRTN, however corrections for flows of less than 50 vehicles are not provided. As such the predicted levels below may be overly conservative (i.e. higher) than those expected to be experienced on site.

[14] SCT Consulting report *Valley of The Winds Traffic Assessment*, dated 21 December 2021

From the traffic data in Table 23 and a review of receivers adjoining the affected roads traffic noise levels have been predicted to the nearest identified receivers on each road using the following method and assumptions:

- Traffic speed assumed at 50 km/h except for Nailrex Road and Blackstump Way at 100 km/h outside of townships;
- Heavy vehicles are assumed to make up 15 % of total traffic flows;
- When calculating construction traffic flows the daily traffic is assumed to be spread evenly across an 11 hr day period;
- Nailrex Road, Queensborough Street and Black Stump Way assessed as sub-arterial roads per RNP definitions. All other roads assessed as local roads as defined in the RNP;
- Predicted noise levels include an additional +2.5 dB correction for facade reflection as required by the RNP; and
- $L_{Aeq, 1h}$ levels calculated as $L_{A10, 1h}$ predicted using CoRTN - 3 dB per RMS practice.

The additional vehicle flows during construction, particularly on roads carrying very little existing traffic, will increase noise levels noticeable for some residents. However, the total vehicle flows are still low (less than 800 vehicles per day in all cases) in an absolute sense. Calculated noise levels indicate that compliance will be achieved with the RNP during the construction phase at all identified receivers, both for absolute noise levels and the relative increase criteria (where applicable).

Table 24: Summary of construction traffic noise levels

Applicable roads	Assumed future year base daily traffic volume (2023)	Additional construction daily traffic volume	Assumed traffic volume with construction and base traffic	Distance to nearest residence, m	Predicted level at nearest residence	Absolute level criteria	Absolute level compliance	Relative increase in $L_{Aeq, 15h}$	Relative increase criteria	Relative increase compliance
Short Street GH Turee Street GH Main Street GH Wyaldra Street GH Moorefield Road (east) GH	100	344	444	50	53 dB $L_{Aeq, 1h}$	55 dB $L_{Aeq, 1h}$	Yes	-	-	-
Moorefield Road (west) GH	50	210	260	35	52 dB $L_{Aeq, 1h}$	55 dB $L_{Aeq, 1h}$	Yes	-	-	-
Wardens Road LV	50	210	260	45	51 dB $L_{Aeq, 1h}$	55 dB $L_{Aeq, 1h}$	Yes	-	-	-
Garland Street LV	50	210	260	15	53 dB $L_{Aeq, 1h}$	55 dB $L_{Aeq, 1h}$	Yes	-	-	-
Mount Hope Road MH	50	244	294	15	54 dB $L_{Aeq, 1h}$	55 dB $L_{Aeq, 1h}$	Yes	-	-	-
Neilrex Road MH	200	244	444	90	54 dB $L_{Aeq, 15h}$	60 dB $L_{Aeq, 15h}$	Yes	4 dB	≤12 dB	Yes
Queensborough Street MH	250	244	494	15	56 dB $L_{Aeq, 15h}$	60 dB $L_{Aeq, 15h}$	Yes	3 dB	≤12 dB	Yes
Black Stump Way MH	400	334	734	10	59 dB $L_{Aeq, 15h}$	60 dB $L_{Aeq, 15h}$	Yes	3 dB	≤12 dB	Yes

Notes: GR Girragulang Road cluster
MH Mount Hope cluster
LV Leadville cluster

10.0 SUMMARY

An assessment of operational and construction noise for the proposed Valley of the Winds wind farm has been carried out in accordance with the requirements of the applicable Planning Secretary's Environmental Assessment Requirements (SEARs). The assessment is based on the proposed wind farm layout comprising one hundred and forty-eight (148) wind turbines and related infrastructure.

Operational noise associated with the proposed wind turbines has been assessed in accordance with the NSW EPA *NSW Wind Energy: Noise Assessment Bulletin* (NSW Noise Assessment Bulletin) as required by the SEARs.

Noise modelling was carried out based on three (3) candidate turbine models which have been selected by the proponent as being representative of the size and type of wind turbines which could be used for this wind farm. The results demonstrate that the proposed wind turbines are predicted to achieve compliance with the applicable base noise limits specified in the NSW Noise Assessment Bulletin at all of assessed receivers for two (2) of the three (3) candidate turbine models. For the remaining candidate turbine model, wind turbine noise levels were predicted to comply with the applicable noise limits at all but one receiver where the noise limit at 10 m/s is marginally exceeded by up to 0.2 dB.

The assessment results demonstrate that cumulative noise considerations associated with the wind farm can be practically managed for receivers near to both the proposed Valley of the Winds wind farm and the nearby approved Liverpool Range Wind Farm. In particular, the predicted increases in wind turbine noise levels as a result of the cumulative influence of each project are small and not sufficient to affect the compliance outcomes for either of the assessed projects.

As required by the NSW Noise Assessment Bulletin, consideration was also given to the potential for special noise characteristics. Based on review of the manufacturer specification and prediction of C weighted noise levels, adjustments for special noise characteristics have not been applied to the predicted noise levels presented in this assessment.

The assessment has also considered operational noise associated with the proposed related infrastructure comprising a battery energy storage system and three (3) substations. Predicted noise levels have been assessed in accordance with the NSW EPA *Noise Policy for Industry* and demonstrated that the related infrastructure complied with the most stringent night-time project noise trigger level at all receivers.

A preliminary construction noise and vibration assessment has also been conducted, including assumptions for typical equipment items and work practices as well as details of the relevant NSW guidelines and preliminary noise management recommendations. The assessment was undertaken in accordance with the NSW DECC publications *Interim Construction Noise Guideline* and *Assessing Vibration: A Technical Guideline* and confirmed that a construction noise and vibration can be appropriately managed using standard good practice measures.

An assessment of traffic noise impacts associated with construction operations has also been conducted in accordance with the NSW EPA *Road Noise Policy*.

Once a more detailed schedule of equipment and plant items, construction method, construction traffic and construction work areas are known, a detailed Construction Noise and Vibration Management Plan should be prepared. It should include site and process specific noise management work practices designed to mitigate the noise and vibration impact of construction activities, including blasting and traffic.

The findings of this noise assessment indicates that with appropriate work practices, feasible and reasonable mitigation, planning and management techniques, the proposed Valley of the Winds wind farm can be designed, constructed, operated and decommissioned to satisfy the requirements specified in the project SEARs.

APPENDIX A GLOSSARY OF TERMINOLOGY

Term	Definition	Abbreviation
A-weighting	A method of adjusting sound levels to reflect the human ear's varied sensitivity to different frequencies of sound.	See discussion below this table.
A-weighted 90th centile	The A-weighted pressure level that is exceeded for 90 % of a defined measurement period. It is used to describe the underlying background sound level in the absence of a source of sound that is being investigated, as well as the sound level of steady, or semi steady, sound sources.	L_{A90}
A-weighted average noise level	The equivalent continuous (time-averaged) A-weighted sound level. This is commonly referred to as the average noise level. The suffix "t" represents the time period to which the noise level relates, e.g. (8 h) would represent a period of 8 hours, (15 min) would represent a period of 15 minutes and (2200-0700) would represent a measurement time between 10 pm and 7 am.	$L_{Aeq\,(t)}$
A-weighted maximum noise level	The A-weighted maximum noise level. The highest noise level which occurs during the measurement period.	L_{Amax}
C-weighting	The process by which noise levels are corrected to account for non-linear frequency response of the human ear at high noise levels (typically greater than 100 decibels).	See discussion below this table
Decibel	The unit of sound level.	dB
Hertz	The unit for describing the frequency of a sound in terms of the number of cycles per second.	Hz
Octave Band	A range of frequencies. Octave bands are referred to by their logarithmic centre frequencies, these being 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz for the audible range of sound.	-
Peak Particle Velocity	The measure of the vibration aptitude, zero to maximum. Used for building structural damage assessment	PPV
Sound power level	A measure of the total sound energy emitted by a source, expressed in decibels.	L_W
Sound pressure level	A measure of the level of sound expressed in decibels.	L_p
Special Audible Characterises	A term used to define a set group of Sound characteristics that increase the likelihood of adverse reaction to the sound. The characteristics comprise tonality, impulsiveness and amplitude modulation.	SAC
Tonality	A characteristic to describe sounds which are composed of distinct and narrow groups of audible sound frequencies (e.g. whistling or humming sounds).	-

The basic quantities used within this document to describe noise adopt the conventions outlined in ISO 1996-1:2016 *Acoustics - Description measurement and assessment of environmental noise – Basic quantities and assessment procedures*. Accordingly, all frequency weighted sound pressure levels are expressed as decibels (dB) in this report. For example, sound pressure levels measured using an "A" frequency weighting are expressed as dB L_A. Alternative ways of expressing A-weighted decibels such as dBA or dB(A) are therefore not used within this report.

APPENDIX B DESCRIPTION OF SOUND

Sound is an important feature of the environment in which we live; it provides information about our surroundings and influences our overall perception of amenity and environmental quality.

While sound is a familiar concept, its description can be complex. A glossary of terms and abbreviations is provided in Appendix A.

This appendix provides general information about the definition of sound and the ways that different sound characteristics are described.

B1 Definition of sound

Sound is a term used to describe very small and rapid changes in the pressure of the atmosphere. Importantly, for pressure fluctuations to be considered sound, the rise and fall in pressure needs to be repeated at rates ranging from tens to thousands of times per second.

These small and repetitive fluctuations in pressure can be caused by many things such as a vibrating surface in contact with the air (e.g. the cone of a speaker) or turbulent air movement patterns. The common feature is a surface or region of disturbance that displaces the adjacent air, causing a very small and localised compression of the air, followed by a small expansion of the air.

These repeated compressions and expansions then spread into the surrounding air as waves of pressure changes. Upon reaching the ear of an observer, these waves of changing pressure cause structures within the ear to vibrate; these vibrations then generate signals which can be perceived as sounds.

The waves of pressure changes usually occur as complex patterns, comprising varied rates and magnitudes of pressure changes. The pattern of these changes will determine how a sound spreads through the air and how the sound is ultimately perceived when it reaches the ear of an observer.

B2 Physical description of sound

There are many situations where it can be useful to objectively describe sound, such as the writing or recording of music, hearing testing, measuring the sound environment in an area or evaluating new man-made sources of sound.

Sound is usually composed of complex and varied patterns of pressure changes. As a result, several attributes are used to describe sound. Two of the most fundamental sound attributes are:

- sound pressure; and
- sound frequency.

Each of these attributes is explained in the following sections, followed by a discussion about how each of these attributes varies.

B2.1 Sound pressure

The compression and expansion of the air that is associated with the passage of a sound wave results in changes in atmospheric pressure. The pressure changes associated with sound represent very small and repetitive variations that occur amidst much greater pressures associated with the atmosphere.

The magnitude of these pressure changes influences how quiet or loud a sound will be; the smaller the pressure change, the quieter the sound, and vice versa. The perception of loudness is complex though, and different sounds can seem quieter or louder for reasons other than differences in pressure changes.

To provide some context, Table 25 lists example values of pressure associated with the atmosphere and different sounds. The key point from these example values is that even an extremely loud sound equates to a change in pressure that is thousands of times smaller than the typical pressure of the atmosphere.

Table 25: Atmospheric pressure versus sound pressure – example values of pressure

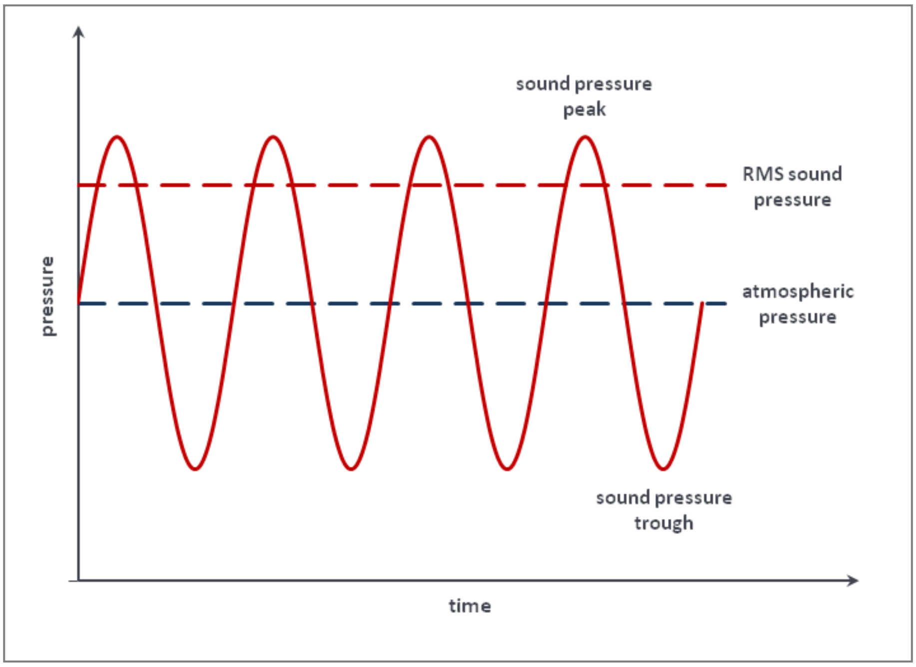
Example	Pascals	Bars	Pounds per Square Inch (PSI)
Atmospheric pressure	100,000	1	14.5
Pressure change due to weather front	10,000	0.1	1.5
Pressure change associated with sound at the threshold of pain	20	0.0002	0.003
Pressure change associated with sound at the threshold of hearing	0.00002	0.0000000002	0.000000003

The pressure values in Table 25 also show that the range of pressure changes associated with quiet and loud sounds span over a very large range, albeit still very small changes compared to atmospheric pressure. To make the description of pressure changes more practical, sound pressure is expressed in decibels or dB.

To illustrate the pressure variation associated with sound, Figure 6 shows the repetitive rise and fall in pressure of a very simple and steady sound. This figure illustrates the peaks and troughs of pressure changes relative to the underlying pressure of the atmosphere in the absence of sound. The magnitude of the change in pressure caused by the sound is then described as the sound pressure level. Since the magnitude of the change is constantly varying, the sound pressure may be defined in terms of:

- Peak sound pressure levels: the maximum change in pressure relative to atmospheric pressure i.e. the amplitude as defined by the maximum depth or height of the peaks and troughs respectively; or
- Root Mean Square (RMS) sound pressure levels: the average of the amplitude of pressure changes, accounting for positive changes above atmospheric pressure, and negative pressure changes below atmospheric pressure.

Figure 6: Pressure changes relative to atmospheric pressure associated with sound



B2.2 Frequency

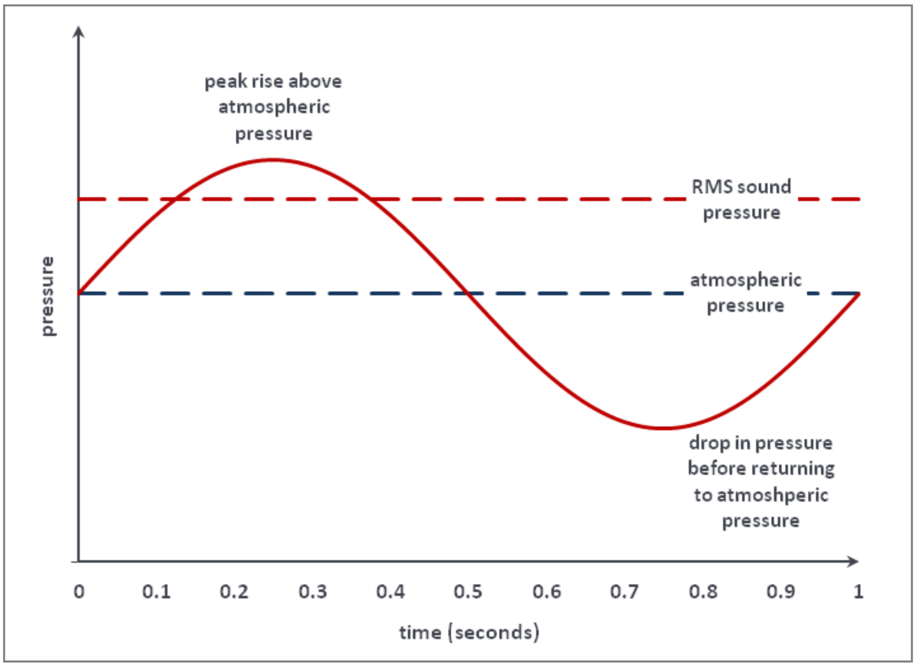
Frequency is a term used to describe the number of times a sound causes the pressure to rise and fall in a given period. The rate of change in pressure is an important feature that determines whether it can be perceived as a sound by the human ear.

Repetitive changes in pressure can occur as a result of a range of factors with widely varying rates of fluctuation. However, only a portion of these fluctuations can be perceived as sound. In many cases, the rate of fluctuation will either be too slow or too fast for the human ear to detect the pressure change as a sound. For example, local fluctuations in atmospheric pressure can be created by someone waving their hands back and forth through the air; the reason this cannot be perceived as a sound is the rate of fluctuation is too slow.

At the rates of fluctuation that can be detected as sound, the rate will influence the character of the sound that is perceived. For example, slow rates of pressure change correspond to rumbling sounds, while fast rates correspond to whistling sounds.

The rate of fluctuation is numerically described in terms of the number of pressure fluctuations that occur in a single second. Specifically, it is the number of cycles per second of the pressure rising above, falling below, and then returning to atmospheric pressure. The number of these cycles per second is expressed in Hertz (Hz). This concept of cycles per second is illustrated in Figure 7 which illustrates a 1 Hz pressure fluctuation. The figure provides a simple illustration of a single cycle of pressure rise and fall occurring in a period of a single second.

Figure 7: Illustration of a pressure fluctuation with a frequency of 1 Hz



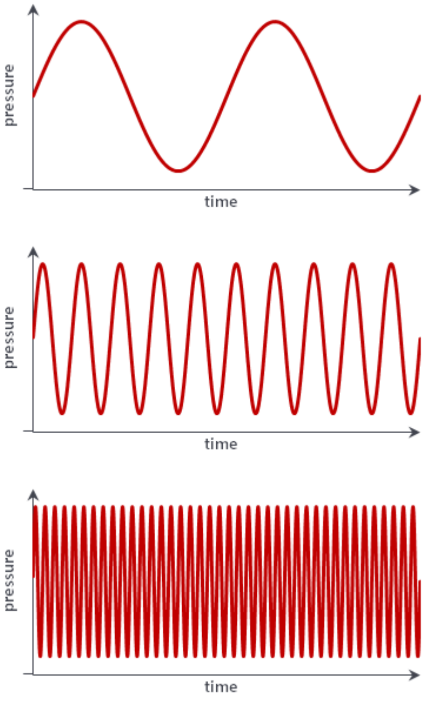
The rate that sound pressure rises and falls will vary depending on the source of the sound. For example, the surface of a tuning fork vibrates at a specific rate, in turn causing the pressure of the adjacent air to fluctuate at the same rate. Recalling the idea of pressure fluctuations from someone waving their hands, the pressure would fluctuate at the same rate as the hands move back and forth; a few times a second translating to a very low frequency below our hearing range (termed an infrasonic frequency). Examples of low and high frequency sound are easily recognisable, such as the low frequency sound of thunder, and the high frequency sound of crashing cymbals. To demonstrate the differences in the patterns of different frequencies of sound, Figure 8 illustrates the relative rates of pressure change for low, mid and high frequency sounds. Note that in each case the amplitude of the pressure changes remains the same; the only change is the number of fluctuations in pressure that occur over time.

Figure 8: Examples of the rate of change in pressure fluctuations for low, mid and high frequencies

Low frequency sounds: 20 to 200 Hz

Mid-frequency sounds: 200 to 800 Hz

High frequency sounds: greater than 800 Hz



B2.3 Sound pressure and frequency variations

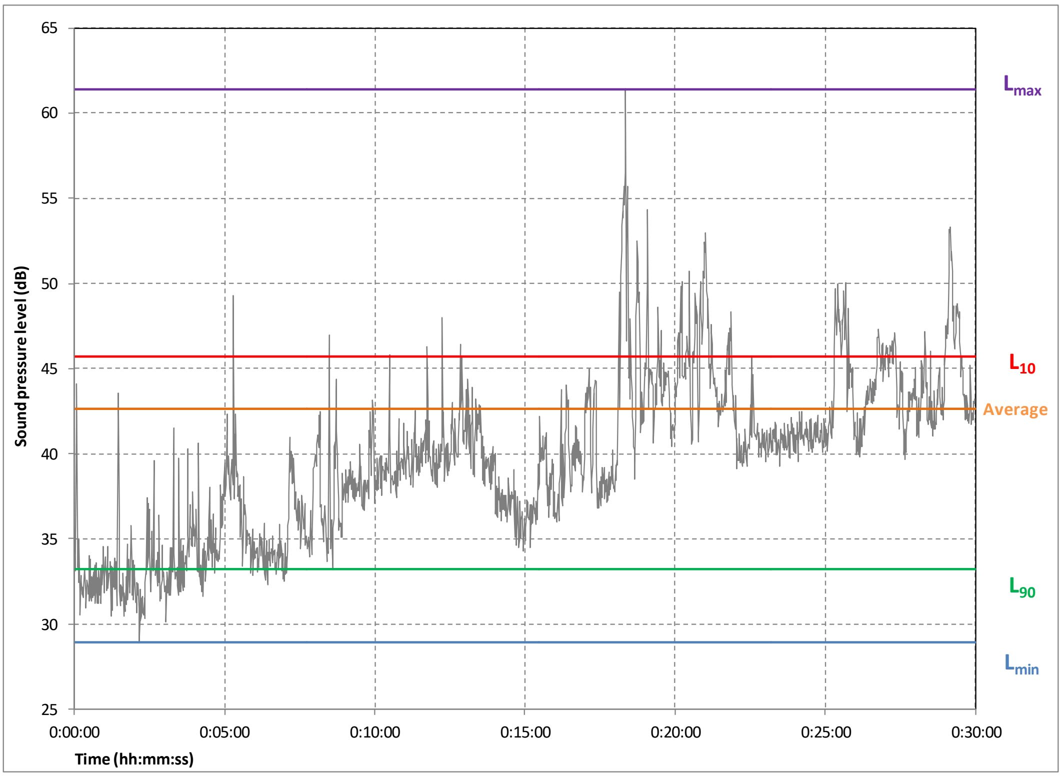
The preceding sections describe important aspects of the nature of sound, the changes in pressure and the changes in the rate of pressure fluctuations.

The simplest type of sound comprises a single constant sound pressure level and a single constant frequency. However, most sounds are made up of many frequencies, and may include low, mid and high frequencies. Sounds that are made up of a relatively even mix of frequencies across a broad range of frequencies are referred to as being 'broad band'. Common examples of broad band sounds include flowing water, the rustling of leaves, ventilation fans and traffic noise.

Further, sound quite often changes from moment to moment, in terms of both pressure levels and frequencies. The time varying characteristics of sound are important to how we perceive sound. For example, rapid changes in sound level produced by voices provide the component of sound that we interpret as intelligible speech. Variations in sound pressure levels and frequencies are also features which can draw our attention to a new source of sound in the environment.

To demonstrate this, Figure 9 illustrates an example time-trace of total sound pressure levels which varies with time. This variation presents challenges when attempting to describe sound pressure levels. As a result, multiple metrics are generally needed to describe sound pressure, such as the average, minimum or maximum noise levels. Other ways of describing sound include statistics for describing how often a defined sound pressure level is exceeded; for example, typical upper sound levels are often described as an L_{10} which refers to the sound pressure exceeded for 10 % of the time, or typical lower levels or lulls which are often described as an L_{90} which refers to the sound exceeded for 90 % of the time.

Figure 9: Example of noise metrics that may be used to measure a time-varying sound level



This example illustrates variations in terms of just total sound pressure levels, but the variations can also relate to the frequency of the sound, and frequently the number of sources affecting the sound.

These types of variations are an inherent feature of most sound fields and are an important point of context in any attempt to describe sound.

B3 Hearing and perception of sound

This section provides a discussion of:

- The use of the decibel to practically describe sound levels in a way that corresponds to the pressure levels the human ear can detect as sounds; and
- The relationship between sound frequency and human hearing.

The section concludes with a discussion of some of the complicating non-acoustic factors that influence our perception of sound.

B3.1 Sound pressure and the decibel

Previous sections discussed the wide range of small pressure fluctuations that the ear can detect as sound. Owing to the wide range of these fluctuations, the way we hear sound is more practically described using the decibel (dB). The decibel system serves two key purposes:

- Compressing the numerical range of the quietest and loudest sounds commonly experienced.

  As an indication of this benefit, the pressure of the loudest sound that might be encountered is around a million times greater than the quietest sound that can be detected. In contrast, the decibel system reduces this to a range of approximately 0-120 dB.

- Consistently representing sound pressure level changes in a way that correlate more closely with how we perceive sound pressure level changes.

  For example, a 10 dB change from 20-30 dB will generally be subjectively like a 10 dB change from 40-50 dB. However, expressed in units of pressure as Pascals, the 40-50 dB change is ten times greater than the 20-30 dB change. For this reason, sound pressure changes cannot be meaningfully communicated in terms of units of pressure such as Pascals.

Sound pressure levels in most environments are highly variable, so it can be misleading to describe what different ranges of sound pressure levels correspond to. However, as a broad indication, Table 26 provides some example ranges of sound pressure levels, expressed in both dB and units of pressure.

Table 26: Example sound pressure levels that might be experienced in different environments

Environment	Example sound pressure level	
Outside in an urban area with traffic noise	50-70 dB	0.006-0.06 Pa
Outside in a rural area with distant sounds or moderate wind rustling leaves	30-50 dB	0.0006-0.006 Pa
Outside in a quiet rural environment in calm conditions	20-30 dB	0.0002-0.0006 Pa
Inside a quiet bedroom at night	<20 dB	0.0002 Pa

The impression of how much louder or quieter a sound is, will be influenced by the magnitude of the change in sound pressure. Other important factors will also influence this, such as the frequency of the sound which is discussed in the following section. However, to provide a broad indication, Table 27 provides some examples of how changes in sound pressure levels, for a sound with the same character, can be perceived.

Table 27: Perceived changes in sound pressure levels

Sound pressure level change	Indicative change in perceived sound
1 dB	Unlikely to be noticeable
2-3 dB	Likely to be just noticeable
4-5 dB	Clearly noticeable change
10 dB	Distinct change - often subjectively described as halving or doubling the loudness

The example sound pressure level changes in Table 27 are based on side by side comparison of a steady sample of sound heard at different levels. In practice, changes in sound pressure levels may be more difficult to perceive for a range of reasons, including the presence of other sources of sound, or gradual changes which occur over a longer period.

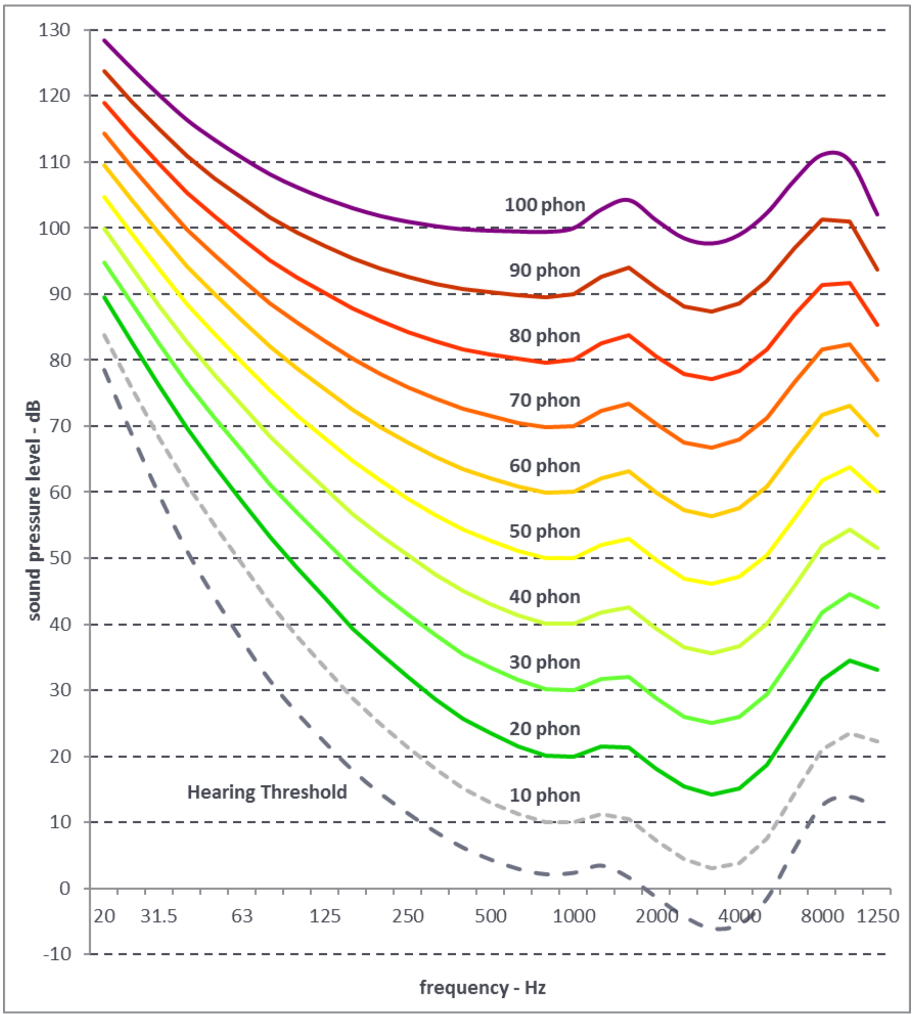
B3.2 Sound frequency and loudness

Although sound pressure level and the sensation of loudness are related, the sound pressure level is not a direct measure of how loud a sound appears to humans. Human perception of sound varies and depends on a number of physical attributes, including frequency, level and duration.

An example of the relationship between the sensation of loudness and frequency is demonstrated in Figure 10. The chart presents equal loudness curves for sounds of different frequencies expressed in 'phons'. Each point on the phon curves represents a sound of equal loudness. For example, the 40 phon curve shows that a sound level of 100 dB at 20 Hz (a very low frequency sound) would be of equal loudness to a level of 40 dB at 1,000 Hz (a whistling sound) or approximately 50 dB at just under 8,000 Hz (a very high pitch sound). The information presented is based on an international standard[15] that defines equal loudness levels for sounds comprising individual frequencies. In practice, sound is usually composed of many different frequencies, so this type of data can only be used as an indication of how different frequencies of sound may be perceived. An individual's perceptions of sound can also vary significantly. For example, the lower dashed line in Figure 10 shows the threshold of hearing, which represents the sounds an average listener could correctly identify at least 50 % of the time. However, these thresholds represent the average of the population. In practice, an individual's hearing threshold can vary significantly from these values, particularly at the low frequencies.

[15] ISO 226:2003 *Acoustics - Normal equal-loudness-level contours*, 2003

Figure 10: Equal loudness contours for pure tone sounds



The noise curves in Figure 10 demonstrate that human hearing is most sensitive at frequencies from 500 to 4,000 Hz, which usefully corresponds to the main frequencies of human speech. The contours also demonstrate that sounds at low frequencies must be at much higher sound pressure levels to be judged equally loud as sounds at mid to high frequencies.

To account for the sensitivity of the ear to different frequencies, a set of adjustments were developed to enable sound levels to be measured in a way that more closely aligns with human hearing. Sound levels adjusted in this way are referred to as A-weighted sound levels.

B3.3 Interpretation of sound and noise

Human interpretation of sound is influenced by many factors other than its physical characteristics, such as how often the sound occurs, the time of day it occurs and a person's attitude towards the source of the sound.

For example, the sound of music can cause very different reactions, from relaxation and pleasure through to annoyance and stress, depending on individual preferences, the type of music and the circumstances in which the music is heard. This example illustrates how sound can sometimes be considered noise; a term broadly used to describe unwanted sounds or sounds that have the potential to cause negative reactions.

The effects of excess environmental sound are varied and complicated and may be perceived in various ways including sensations of loudness, interference with speech communication, interference with working concentration or studying, disruption of resting/leisure periods, and disturbance of sleep. These effects can give rise to behavioural changes such as avoiding the use of exposed external spaces, keeping windows closed, or timing restful activities to avoid the most intense periods of disruption. Prolonged annoyance or interference with normal patterns can lead to possible effects on mental and physical health. In this respect, the World Health Organization (preamble to the *Constitution of the World Health Organization*, 1946) defines health in the following broad terms:

> *A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*

The World Health Organization Guidelines for Community Noise (Berglund, Lindvall, & Schwela, 1999) documents a relationship between the definition of health and the effects of community noise exposure by noting that:

> *This broad definition of health embraces the concept of well-being, and thereby, renders noise impacts such as population annoyance, interference with communication, and impaired task performance as 'health' issues.*

The reaction that a community has to sound is highly subjective and depends on a range of factors including:

- The hearing threshold of individuals across the audible frequency range. These thresholds vary widely across the population, particularly at the lower and upper ends of the audible frequency range. For example, at low frequencies the distribution of hearing thresholds varies above and below the mean threshold by more than 10 dB;
- The attitudes and sensitivities of individuals to sound, and their expectations of what is considered an acceptable level of sound or intrusion. This in turn depends on a range of factors such as general health and the perceived importance of sound amongst other factors relevant to overall amenity perception;
- The absolute sound pressure level of the sound in question. The threshold for the onset of community annoyance varies according to the type of sound; above such thresholds, the percentage of the population annoyed generally increases with increasing sound pressure level;
- The sound pressure level of the noise relative to background noise conditions in the area, and the extent to which general background noise may offer beneficial masking effects;
- The characteristics of the sound in question such as whether the sound is constant, continually varies, or contains distinctive audible features such as tones, low frequency components or impulsive sound which may draw attention to the noise;
- The site location and the compatibility of the source in question with other surrounding land uses. For example, whether the source is in an industrial or residential area;

- The attitudes of the community to the source of the sound. This may be influenced by factors such as the extent to which those responsible for the sound are perceived to be adopting reasonable and practicable measures to reduce their emissions, whether the activity is of local or national significance and whether the noise producer actively consults and/or liaises with the community; and
- The times when the sound is present, the duration of exposure to increased sound levels, and the extent of respite periods when the sound is reduced or absent (for example, whether the sound ceases at weekends).

The combined influence of the above considerations means that physical sound levels are only one factor influencing community reaction to sound. Importantly, this means that individual reactions and attitudes to the same type and level of sound will vary within a community.

APPENDIX C TURBINE COORDINATES

Table 28 sets out the coordinates of the proposed turbine layout.

(Layout dated 10 November 2021 as supplied by the proponent).

Table 28: Proposed wind turbine coordinates – GDA 2020 Zone 55

Turbine	Easting, m	Northing, m	Terrain elevation, m
GR2	759,945	6,458,232	600
GR3	760,267	6,458,557	610
GR4	760,587	6,458,894	610
GR5	760,345	6,459,441	599
GR6	760,398	6,460,059	610
GR7	760,674	6,460,478	620
GR8	760,633	6,461,526	610
GR9	760,499	6,462,088	618
GR10	760,559	6,462,572	621
GR11	760,663	6,463,035	630
GR12	760,733	6,463,509	630
GR13	758,438	6,459,581	620
GR14	758,775	6,460,045	620
GR15	758,711	6,460,550	630
GR16	758,513	6,461,087	625
GR17	758,101	6,461,652	660
GR18	758,392	6,462,051	680
GR19	758,581	6,462,466	690
GR20	758,622	6,462,951	695
GR21	759,036	6,463,236	671
GR22	758,870	6,463,773	644
GR23	757,524	6,459,697	631
GR24	757,475	6,460,158	640
GR25	757,356	6,460,645	666
GR26	757,170	6,461,574	680
GR27	757,371	6,461,984	672
GR28	756,639	6,458,842	616
GR29	756,257	6,459,395	629
GR30	756,756	6,459,623	645
GR31	756,561	6,460,198	640

Turbine	Easting, m	Northing, m	Terrain elevation, m
GR32	756,394	6,461,194	630
GR33	756,157	6,462,109	610
GR34	756,642	6,462,426	620
GR35	755,094	6,459,083	610
GR36	755,296	6,459,452	619
GR37	755,282	6,460,073	640
GR38	755,578	6,460,433	640
GR40	753,535	6,457,743	622
GR41	753,568	6,458,121	620
GR42	753,648	6,458,775	620
GR43	754,027	6,459,161	620
GR44	754,338	6,459,538	620
GR45	754,591	6,459,956	635
GR46	754,528	6,460,559	610
GR47	754,418	6,461,745	600
GR48	754,829	6,462,101	600
GR49	755,071	6,462,557	610
GR50	755,294	6,462,994	600
GR51	756,547	6,462,873	593
GR52	756,616	6,463,255	590
GR53	760,537	6,461,040	600
LV3	750,413	6,451,624	580
LV4	749,149	6,450,441	560
LV5	748,725	6,450,997	570
LV6	749,248	6,451,227	590
LV7	749,743	6,451,476	600
LV8	749,804	6,452,596	598
LV9	743,857	6,450,601	559
LV10	744,180	6,451,055	588
LV11	744,639	6,451,296	584
LV12	745,108	6,451,518	599
LV13	745,623	6,451,741	593
LV14	746,242	6,452,428	590

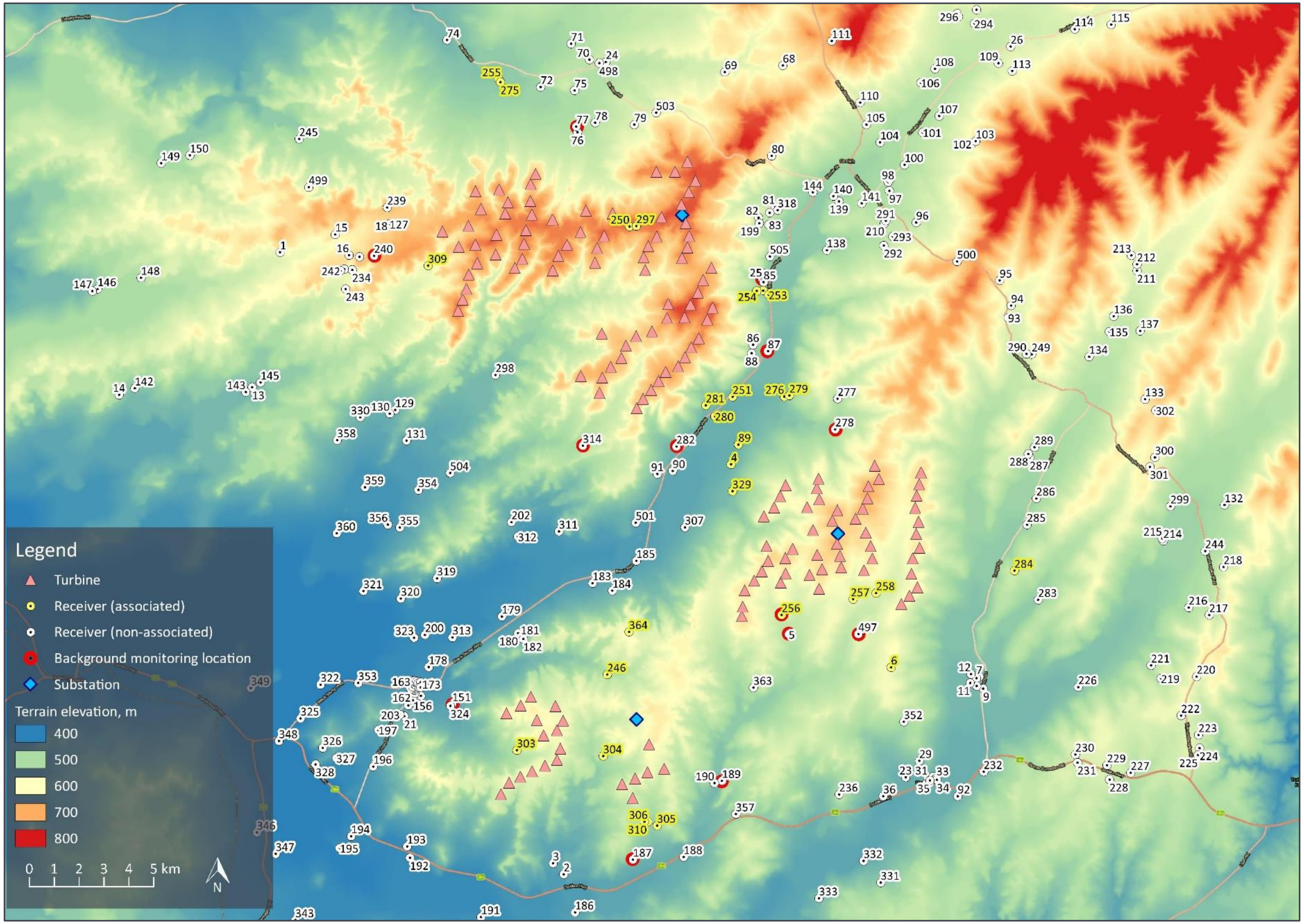
Turbine	Easting, m	Northing, m	Terrain elevation, m
LV15	746,104	6,453,165	606
LV16	746,353	6,453,549	590
LV17	746,047	6,454,131	568
LV18	745,568	6,452,958	610
LV19	745,296	6,453,566	610
LV20	744,079	6,453,843	605
LV21	744,651	6,454,155	620
LV22	745,062	6,454,505	575
LV23	746,111	6,451,980	577
MH3	749,310	6,466,082	644
MH4	750,188	6,467,172	692
MH5	749,563	6,466,461	665
MH6	749,886	6,466,815	680
MH7	750,476	6,467,537	709
MH8	750,973	6,467,766	690
MH9	751,254	6,468,130	690
MH10	751,504	6,468,529	716
MH11	751,806	6,468,890	739
MH12	752,151	6,469,642	738
MH13	752,361	6,470,113	760
MH14	747,817	6,466,698	657
MH15	747,065	6,467,378	680
MH16	747,931	6,467,309	683
MH17	748,267	6,467,739	690
MH18	748,696	6,468,097	670
MH19	748,878	6,468,598	662
MH20	749,287	6,468,979	653
MH21	747,908	6,469,081	649
MH22	749,924	6,469,164	680
MH23	750,527	6,469,695	715
MH24	751,233	6,469,728	753
MH25	751,472	6,470,237	770
MH26	750,576	6,470,263	730

Turbine	Easting, m	Northing, m	Terrain elevation, m
MH27	751,772	6,470,723	733
MH28	751,977	6,471,225	709
MH29	752,311	6,471,722	673
MH30	751,131	6,472,105	719
MH31	751,344	6,472,531	720
MH32	751,417	6,472,993	730
MH33	751,276	6,473,502	733
MH34	751,106	6,474,247	741
MH35	751,406	6,474,747	724
MH36	751,671	6,475,203	752
MH37	751,352	6,475,975	730
MH38	750,845	6,475,562	720
MH39	750,101	6,475,563	720
MH41	749,651	6,471,622	650
MH42	749,585	6,472,140	692
MH43	749,773	6,472,587	720
MH44	750,116	6,472,965	721
MH45	750,306	6,473,747	739
MH46	747,638	6,471,923	682
MH47	747,721	6,472,511	710
MH48	748,002	6,472,993	743
MH49	748,343	6,473,899	707
MH50	745,939	6,471,612	715
MH51	746,166	6,472,195	720
MH52	746,507	6,472,634	725
MH53	747,056	6,473,147	714
MH54	747,268	6,474,011	720
MH55	744,419	6,471,709	698
MH56	744,718	6,472,071	720
MH57	744,783	6,472,678	730
MH58	744,861	6,473,223	730
MH59	745,929	6,473,660	720
MH60	745,097	6,473,851	723

Turbine	Easting, m	Northing, m	Terrain elevation, m
MH61	745,041	6,474,392	719
MH62	745,051	6,475,077	698
MH63	745,247	6,475,482	680
MH64	742,133	6,469,995	730
MH65	742,319	6,470,443	719
MH66	742,474	6,470,870	663
MH67	742,564	6,471,442	710
MH68	742,903	6,471,899	720
MH69	743,646	6,472,241	700
MH70	743,673	6,473,041	723
MH71	744,029	6,473,892	717
MH72	744,138	6,474,344	715
MH73	743,784	6,474,856	720
MH74	742,160	6,472,561	676
MH75	742,831	6,472,640	730
MH76	741,505	6,473,174	692
MH77	742,548	6,473,402	690
MH78	743,053	6,474,077	707
MH79	742,833	6,474,787	698

APPENDIX D SITE TOPOGRAPHY

Figure 11: Terrain elevation map



APPENDIX E RECEIVER COORDINATES

Table 29 sets out the fifty-seven (57) receivers identified by the proponent within 3 km of the proposed turbines considered in the environmental noise assessment, together with their respective distance to the nearest turbine.

This includes twenty-two (22) associated receivers where a noise agreement has been formalised between the landowners and the proponent.

(Data dated 6 December 2021 as supplied by the proponent)

Table 29: Receivers within 3 km of the proposed turbines – GDA 2020 Zone 55

Receiver	Easting, m	Northing, m	Terrain elevation, m	Distance to the nearest turbine, m	Nearest turbine
Non-associated receivers					
5	755,422	6,457,014	521	2,026	GR40
18	739,309	6,473,411	642	2,212	MH76
25	754,356	6,471,246	491	2,103	MH29
76	746,932	6,477,152	524	2,375	MH63
77	746,882	6,477,385	515	2,512	MH63
79	749,213	6,477,460	570	2,098	MH39
82	754,208	6,473,729	540	2,764	MH29
83	754,620	6,473,447	510	2,885	MH29
84	754,430	6,471,486	492	2,135	MH29
85	754,408	6,471,141	486	2,179	MH29
86	753,987	6,468,628	512	2,101	MH12
87	754,583	6,468,372	463	2,746	MH12
88	753,928	6,468,284	499	2,210	MH11
90	750,756	6,463,567	440	2,903	MH3
91	750,140	6,463,443	464	2,769	MH3
127	739,381	6,473,473	644	2,148	MH76
151	741,898	6,454,218	435	2,216	LV20
180	744,543	6,457,052	445	2,602	LV22
181	744,652	6,456,901	454	2,434	LV22
182	744,757	6,456,824	462	2,342	LV22
187	749,161	6,447,974	466	2,470	LV4
189	752,739	6,451,131	473	2,381	LV3
190	752,433	6,451,041	466	2,106	LV3
199	754,236	6,473,501	538	2,624	MH29
239	739,288	6,474,137	680	2,420	MH76

Receiver	Easting, m	Northing, m	Terrain elevation, m	Distance to the nearest turbine, m	Nearest turbine
240	738,763	6,472,198	670	2,913	MH76
278	757,286	6,465,236	505	2,095	GR52
282	750,906	6,464,542	458	2,221	MH3
298	743,640	6,467,417	464	2,988	MH64
314	747,146	6,464,576	510	2,229	MH14
324	741,826	6,454,138	440	2,275	LV20
363	754,001	6,454,872	510	2,911	GR40
497	758,215	6,457,021	570	2,115	GR2
503	750,094	6,477,939	570	2,335	MH37
505	754,664	6,472,170	494	2,398	MH29
Associated receivers					
4	753,102	6,463,830	450	2,348	GR49
6	759,531	6,455,686	590	2,582	GR2
89	753,396	6,464,622	456	2,503	GR50
246	748,131	6,455,398	518	2,442	LV17
250	749,023	6,473,371	740	869	MH49
251	753,165	6,466,540	456	2,489	MH9
252	754,390	6,470,804	484	2,147	MH13
253	754,612	6,470,636	475	2,314	MH13
254	754,133	6,470,787	493	1,899	MH13
256	755,133	6,457,790	546	1,299	GR35
257	758,006	6,458,422	580	1,242	GR13
258	758,930	6,458,667	555	1,045	GR13
280	752,452	6,465,758	451	2,497	MH8
281	752,090	6,466,196	474	1,930	MH8
297	749,296	6,473,389	735	931	MH44
303	744,500	6,452,362	515	1,047	LV12
304	747,968	6,452,126	505	1,364	LV5
305	750,134	6,449,338	493	1,483	LV4
306	749,757	6,449,494	500	1,131	LV4
309	740,935	6,471,803	595	1,445	MH74
310	749,622	6,449,494	515	1,065	LV4
329	753,160	6,462,752	469	1,616	GR47

APPENDIX F NOISE PREDICTION MODEL

Environmental noise levels associated with wind farms are predicted using engineering methods.

The international standard ISO 9613-2 *Acoustics – Attenuation of sound during propagation outdoors - Part 2: General method of calculation* (ISO 9613-2) has been chosen as the most appropriate method to calculate the level of broadband A-weighted wind farm noise expected to occur at surrounding receptor locations. This method is considered the most robust and widely used international method for the prediction of wind farm noise.

The use of this standard is supported by international research publications, measurement studies conducted by Marshall Day Acoustics and direct reference to the standard in the South Australia EPA W*ind farms environmental noise guidelines*, NZS 6808:2010 *Acoustics – Wind farm noise* and AS 4959:2010 *Acoustics – Measurement, prediction and assessment of noise from wind turbine generators.*

The standard specifies an engineering method for calculating noise at a known distance from a variety of sources under meteorological conditions favourable to sound propagation. The standard defines favourable conditions as downwind propagation where the source blows from the source to the receiver within an angle of ±45 degrees from a line connecting the source to the receiver, at wind speeds between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground. Equivalently, the method accounts for average propagation under a well-developed moderate ground based thermal inversion. In this respect, it is noted that at the wind speeds relevant to noise emissions from wind turbines, atmospheric conditions do not favour the development of thermal inversions throughout the propagation path from the source to the receiver.

To calculate far-field noise levels according to the ISO 9613-2, the noise emissions of each turbine are firstly characterised in the form of octave band frequency levels. A series of octave band attenuation factors are then calculated for a range of effects including:

- Geometric divergence;
- Air absorption;
- Reflecting obstacles;
- Screening;
- Vegetation; and
- Ground reflections.

The octave band attenuation factors are then applied to the noise emission data to determine the corresponding octave band and total calculated noise level at receivers.

Calculating the attenuation factors for each effect requires a relevant description of the environment into which the sound propagation such as the physical dimensions of the environment, atmospheric conditions and the characteristics of the ground between the source and the receiver.

Wind farm noise propagation has been the subject of considerable research in recent years. These studies have provided support for the reliability of engineering methods such as ISO 9613-2 when a certain set of input parameters are chosen in combination. Specifically, the studies to date tend to support that the assignment of a ground absorption factor of G = 0.5 for the source, middle and receiver ground regions between a wind farm and a calculation point tends to provide a reliable representation of the upper noise levels expected in practice, when modelled in combination with other key assumptions; specifically all turbines operating at identical wind speeds, emitting sound levels equal to the test measured levels plus a margin for uncertainty (or guaranteed values), at a temperature of 10 ^{o}C and relative humidity of 70 % to 80 %, with specific adjustments for screening and ground effects as a result of the ground terrain profile.

In support of the use of ISO 9613-2 and the choice of G = 0.5 as an appropriate ground characterisation, the following references are noted:

- A factor of G = 0.5 is frequently applied in Australia for general environmental noise modelling purposes as a way of accounting for the potential mix of ground porosity which may occur in regions of dry/compacted soils or in regions where persistent damp conditions may be relevant
- NZS 6808:2010 refers to ISO 9613-2 as an appropriate prediction method for wind farm noise, and notes that soft ground conditions should be characterised by a ground factor of G = 0.5
- In 1998, a comprehensive study (commonly cited as the Joule Report), part funded by the European Commission found that the ISO 9613-2 model provided a robust representation of upper noise levels which may occur in practice, and provided a closer agreement between predicted and measured noise levels than alternative standards such as CONCAWE and ENM. Specifically, the report indicated the ISO 9613-2 method generally tends to marginally over predict noise levels expected in practice
- The UK Institute of Acoustics journal dated March/April 2009 published a joint agreement between practitioners in the field of wind farm noise assessment (the UK IOA 2009 joint agreement), including consultants routinely employed on behalf of both developers and community opposition groups, and indicated the ISO 9613-2 method as the appropriate standard and specifically designated G = 0.5 as the appropriate ground characterisation. This agreement was subsequently reflected in the recommendations detailed in the UK Institute of Acoustics publication *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* (the UK Institute of Acoustics guidance). It is noted that these publications refer to predictions made at receiver heights of 4 m. Predictions in Australia are generally based on a lower prediction height of 1.5 m which tends to result in higher ground attenuation for a given ground factor, however conversely, predictions in Australia do not generally incorporate a -2 dB factor (as applied in the UK) to represent the relationship between L_{Aeq} and L_{A90} noise levels. The result is that these differences tend to balance out to a comparable approach and thus supports the use of G = 0.5 in the context of Australian prediction methods.

A range of measurement and prediction studies[16, 17, 18] for wind farms in which Marshall Day Acoustics' staff have been associated in have provided further support for the use of ISO 9613-2 and G = 0.5 as an appropriate representation of typical upper noise levels expected to occur in practice.

The findings of these studies demonstrate the suitability of the ISO 9613-2 method to predict the propagation of wind turbine noise for:

- The types of noise source heights associated with a modern wind farm, extending the scope of application of the method beyond the 30 m maximum source heights considered in the original ISO 9613;
- The types of environments in which wind farms are typically developed, and the range of atmospheric conditions and wind speeds typically observed around wind farm sites. Importantly, this supports the extended scope of application to wind speeds in excess of 5 m/s.

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[16] Bullmore, Adcock, Jiggins & Cand – *Wind Farm Noise Predictions: The Risks of Conservatism*; Presented at the Second International Meeting on Wind Turbine Noise in Lyon, France September 2007.

[17] Bullmore, Adcock, Jiggins & Cand – *Wind Farm Noise Predictions and Comparisons with Measurements*; Presented at the Third International Meeting on Wind Turbine Noise in Aalborg, Denmark June 2009.

[18] Delaire, Griffin, & Walsh – *Comparison of predicted wind farm noise emission and measured post-construction noise levels at the Portland Wind Energy Project in Victoria, Australia*; Presented at the Fourth International Meeting on Wind Turbine Noise in Rome, April 2011.

In addition to the choice of ground factor referred to above, adjustments to the ISO 9613-2 standard for screening and valleys effects are applied based on recommendations of the Joule Report, UK IOA 2009 joint agreement and the UK Institute of Acoustics guidance. The following adjustments are applied to the calculations:

- Screening effects as a result of terrain are limited to 2 dB;
- Screening effects are assessed based on each turbine being represented by a single noise source located at the maximum tip height of the turbine rotor; and
- An adjustment of 3 dB is added to the predicted noise contribution of a turbine if the terrain between the turbine and receiver in question is characterised by a significant valley. A significant valley is defined as a situation where the mean sound propagation height is at least 50 % greater than it would be otherwise over flat ground.

The adjustments detailed above are implemented in the wind turbine calculation procedure of the SoundPLAN 8.2 software used to conduct the noise modelling. The software uses these definitions in conjunction with the digital terrain model of the site to evaluate the path between each turbine and receiver pairing, and then subsequently applies the adjustments to each turbine's predicted noise contribution where appropriate.

APPENDIX G TABULATED BACKGROUND NOISE LEVELS

Table 30: Background noise levels, dB L_{A90}

Receiver	Hub height wind speed, m/s																	
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5 [1]	22.6	22.8	23.4	24.2	25.3	26.5	28.0	29.6	31.3	33.1	34.9	36.8	38.6	40.5	42.2	43.8	45.3	46.6
25 [2]	-	28.6	28.6	28.6	28.8	29.0	29.4	29.9	30.4	31.1	31.9	32.9	33.9	35.1	36.4	37.9	39.5	41.2
77 [2]	22.1	22.4	22.8	23.3	23.8	24.3	24.9	25.5	26.1	26.8	27.5	28.1	28.8	29.5	30.3	31.0	31.7	32.4
87 [2]	-	-	-	30.4	30.4	30.5	30.9	31.4	32.2	33.1	34.3	35.6	37.1	38.8	40.7	42.8	45.1	47.5
151 [1]	24.8	25.8	26.7	27.5	28.3	29.2	30.0	30.9	31.9	33.1	34.4	35.9	37.6	39.6	41.8	44.4	47.3	50.6
187 [1]	-	24.0	24.0	24.1	24.5	25.2	26.0	27.0	28.2	29.6	31.1	32.8	34.6	36.6	38.6	40.7	42.9	45.2
189 [1]	-	22.8	22.9	23.2	23.6	24.2	25.1	26.1	27.2	28.6	30.1	31.9	33.8	35.9	38.1	40.6	43.3	46.1
240 [2]	24.4	24.6	25.0	25.6	26.4	27.3	28.4	29.7	31.1	32.5	34.0	35.6	37.2	38.8	40.4	41.9	43.4	44.8
256* [1]	-	*27.1*	*27.2*	*27.6*	*28.3*	*29.1*	*30.2*	*31.5*	*32.9*	*34.6*	*36.3*	*38.2*	*40.3*	*42.4*	*44.6*	*46.9*	*49.3*	*51.7*
278 [1]	-	21.5	21.5	22.1	23	24.3	25.8	27.6	29.5	31.5	33.6	35.6	37.6	39.4	41.0	42.3	43.3	43.9
282 [2]	-	-	-	27.7	27.7	28.2	29.1	30.4	31.9	33.7	35.7	37.9	40.1	42.4	44.7	47.0	49.1	51.1
314 [2]	-	23.6	23.6	23.9	24.5	25.4	26.5	27.9	29.5	31.3	33.1	35.2	37.2	39.4	41.5	43.7	45.8	47.8
497 [1]	-	23.1	23.4	24.2	25.4	27.0	28.9	31.0	33.3	35.7	38.1	40.5	42.8	45.0	46.9	48.5	49.7	50.5

Notes: 1 Girragulang Rd Met Mast at 757,267 E / 6,460,616 N (GDA 2020 Zone 55)
2 Mount Hope Met Mast at 751,564 E / 6,470,185 N (GDA 2020 Zone 55)
* Background noise levels measured at this associated receiver are provided for information only

APPENDIX H TABULATED NOISE LIMITS

Table 7: Noise limit, dB L_{A90}

Receiver	Hub height wind speed, m/s																	
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5 [1]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.3	38.1	39.9	41.8	43.6	45.5	47.2	48.8	50.3	51.6
25 [2]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.4	36.1	36.9	37.9	38.9	40.1	41.4	42.9	44.5	46.2
77 [2]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.3	36.0	36.7	37.4
87 [2]	35.4	35.4	35.4	35.4	35.4	35.5	35.9	36.4	37.2	38.1	39.3	40.6	42.1	43.8	45.7	47.8	50.1	52.5
151 [1]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.9	36.9	38.1	39.4	40.9	42.6	44.6	46.8	49.4	52.3	55.6
187 [1]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.1	37.8	39.6	41.6	43.6	45.7	47.9	50.2
189 [1]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.1	36.9	38.8	40.9	43.1	45.6	48.3	51.1
240 [2]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.1	37.5	39.0	40.6	42.2	43.8	45.4	46.9	48.4	49.8
278 [1]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.5	38.6	40.6	42.6	44.4	46.0	47.3	48.3	48.9
282 [2]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.4	36.9	38.7	40.7	42.9	45.1	47.4	49.7	52.0	54.1	56.1
314 [2]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.3	38.1	40.2	42.2	44.4	46.5	48.7	50.8	52.8
497 [1]	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.0	38.3	40.7	43.1	45.5	47.8	50.0	51.9	53.5	54.7	55.5

Notes: 1 Girragulang Rd Met Mast at 757,267 E / 6,460,616 N (GDA 2020 Zone 55)
2 Mount Hope Met Mast at 751,564 E / 6,470,185 N (GDA 2020 Zone 55)

APPENDIX I C-WEIGHTING ASSESSMENT RESULTS

I1 Introduction

Presented below are details of the risk assessment carried out for the purpose of gauging whether penalties for low frequency, as detailed in the NSW Noise Assessment Bulletin, are applicable.

I2 Assessment requirement

Comments and guidance with respect to C-weighted wind turbine is provided in the NSW Noise Assessment Bulletin and discussed in Section 2.1.3 and reproduced below:

> *The presence of excessive low frequency noise that is a repeated characteristic* [i.e. noise from the wind farm that is repeatedly greater than 60 dB(C)] will incur a 5 dB(A) penalty, to be added to the measured noise level for the wind farm, unless a detailed low frequency noise assessment to the satisfaction of the Secretary demonstrates compliance with the proposed criteria for the assessment of low frequency noise disturbance (UK Department for Environment, Food and Rural Affairs (DEFRA, 2005)) for a steady state noise source.*
>
> ** The descriptor shall be in accordance with SA 2009, Section 4*

I3 Prediction method

As highlighted in Section 5.3.3, there are no commonly used, practical methods to accurately predict the wind turbine low frequency noise levels at receivers.

In this case, the C-weighted noise levels at receivers have been estimated considering the candidate turbine GE 6.0-164 has both the highest total sound power levels and the highest sound power levels at low frequencies. The predictions are carried out using a simplified approach based on the same noise modelling methods for A-weighted levels described in Section 3.0, but with the following modifications:

- The range of band frequencies has been expanded to include bands down to the 16 Hz frequency band; and
- The ground factor has been set to G = 0 (hard ground) to account for the increased influence of ground reflections at low frequencies.

C-weighted noise levels have been predicted for the worst-case hub height wind speed of 10 m/s.

I4 Results

Table 31 presents the results of the preliminary C-weighted noise predictions. Results at associated receivers are provided for information only.

Table 31: Predicted C-weighted noise levels for receivers within 3 km of turbines, dB L_{Ceq}

Receiver	Predicted noise level
Non- associated receivers	
5	58.6
18	55.1
25	57.8
76	57.5
77	57.2
79	57.0
82	56.6

Receiver	Predicted noise level
83	56.6
84	57.0
85	57.9
86	58.1
87	57.6
88	58.0
90	57.8
91	57.8
127	55.7
151	55.0
180	55.6
181	55.7
182	55.9
187	53.2
189	53.9
190	54.4
199	56.8
239	55.4
240	55.0
278	58.5
282	58.4
298	56.9
314	57.1
324	55.2
363	55.0
497	58.4
503	55.1
505	56.7
Associated receivers	
4	58.6
6	57.1
89	58.5
246	55.3

Receiver	Predicted noise level
250	63.3
251	58.5
252	58.0
253	57.8
254	58.1
256	60.0
257	61.0
258	61.5
280	58.7
281	59.1
297	63.3
303	61.0
304	58.8
305	55.8
306	56.7
309	59.1
310	56.9
329	59.3

I5 Discussion

The results in Table 31 show that preliminary C-weighted noise levels are predicted to be below the most stringent criteria of 60 dB L_{Ceq} at all assessed non-associated receivers by a margin of at least 1 dB.

While there are limitations on the accuracy of the prediction method used, the approach is considered sufficiently conservative for the purposes of this study. On the basis of the results above, it is considered that risk of low-frequency noise exceeding the criteria is low and therefore it is not appropriate to apply penalty adjustment to account for low-frequency noise.

APPENDIX J EFFECTS OF WIND TURBINE NOISE

In terms of the effect of wind turbine noise, one of the most important consideration is how the sound is perceived. However, judging whether or not a sound is noisy is highly subjective, and depends on many factors including the setting where the sound is heard, the character of the sound, and factors that influence how an individual perceives the sound.

In recognition of the rural settings where wind farms are usually built, wind farms are required to adhere to strict noise controls. Wind farm policies in Australia are among the most stringent international standards, and set limits using a combination of a base (or fixed value) limit and an allowable margin above the background.

J1 Health and amenity

Sound is an important feature of the environment in which we live; it provides information about our surroundings and is a key influence on our overall perception of amenity and environmental quality. Sound is therefore an environmental quality that must be considered as part of any proposal to develop new infrastructure that could influence the sound environment of neighbouring communities.

Excessive or unwanted sound is commonly referred to as noise and can have a range of effects on people, depending on a range of physical and contextual factors. The *Guidelines for Community Noise* 1999 prepared by the World Health Organisation (WHO) provides a health-based framework of guideline limits and values to address the broad definition of health given as:

> *A state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity*

This broad definition means that effects ranging from community annoyance, sleep disturbance and speech interference, through to direct physiological impacts such as hearing damage, are all identified as potential health considerations. An important aspect of this range of considerations is that some effects will be highly dependent on the listener's perception and attitude to the noise in question, such as annoyance, while other effects are primarily related to the level of sound and the direct physiological risks these may represent, such as hearing damage.

Environmental noise policies, including those applied to wind farms, establish objective noise criteria to address these health considerations. In particular, environmental noise policies define criteria which are chosen to prevent direct physiological risks of sound, and minimise as far as practically possible adverse health considerations such as annoyance and sleep disturbance.

Practically minimising the risks of noise effects related to annoyance and sleep disturbance requires the potential range of responses to sound to be considered. In this respect, it is important to note that individual attitudes and reactions to sound are highly variable, and will depend on a complex set of acoustic and non-acoustic factors. These include the level and character of the sound in question, the time of day the sound occurs, the regularity of the sound, the environment in which the sound is heard, the individuals hearing acuity, and an individual's personal opinion and perception of the sound source or development in question. The latter will in turn depend on other complicating factors such as visual impressions of the source in question and the perceived community benefit, or otherwise, of the source in question.

Due to the complexity and range of potential responses to sound, it is not possible to define limits that will guarantee an audible sound will be acceptable to all individuals; this will always be a matter of personal judgement for each individual. Further, it is usually not feasible or practical to design new development or infrastructure to inaudible noise levels. As a result, minimising the risks of noise effects involves setting criteria which prevents the majority of people from being disturbed. This requires regulatory authorities to strike a balance between amenity and development, setting noise limits which are as stringent as can be practically achieved without preventing new development.

This type of approach to noise policy was outlined by the Victorian Department of Health in their 2013 publication on wind farm sound and health which states:

> *Noise standards are used not only for environmental noise (such as wind farms and traffic noise) but also for industry and even household appliances.*
>
> *Noise standards are set to protect the majority of people from annoyance. The wide individual variation in response to noise makes it unrealistic to set standards that will protect everyone from annoyance. A minority of people may still experience annoyance even at sound levels that meet the standard. This is the case not only for wind farms, but for all sources of noise.*

The subject of health effects related to operational wind farms in Australia has been extensively considered by the Commonwealth Government's National Health and Medical Research Council (NHMRC) and the Australian Medical Association; in particular, the NHMRC has undertaken and coordinated a systematic review of evidence related to wind farms and health. The research reviews[19] and public statements[20, 21] produced by these peak health bodies support that, as with any audible sound, wind farm noise can represent a potential source of annoyance or sleep disturbance for some individuals. Their findings did however indicate that there was no reliable evidence to support a relationship between wind farm noise and direct adverse effects on human health.

In July 2012, Health Canada undertook a large-scale epidemiology study in response to community health concerns expressed in relation to wind turbines. The following conclusions[22] were made from this research.

> *The following were not found to be associated with* [Wind Turbine Noise] *exposure:*
>
> - *self-reported sleep (e.g., general disturbance, use of sleep medication, diagnosed sleep disorders);*
> - *self-reported illnesses (e.g., dizziness, tinnitus, prevalence of frequent migraines and headaches) and chronic health conditions (e.g., heart disease, high blood pressure and diabetes); and*
> - *self-reported perceived stress and quality of life.*
>
> *While some individuals reported some of the health conditions above, the prevalence was not found to change in relation to* [Wind Turbine Noise] *levels.*
>
> [...]
>
> *The following was found to be statistically associated with increasing levels of* [Wind Turbine Noise]*:*
>
> - *annoyance towards several wind turbine features (i.e. noise, shadow flicker, blinking lights, vibrations, and visual impacts).*

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[19] *Systematic review of the human health effects of wind* farms 2013, Adelaide University, commissioned by the NMRC

[20] NHMRC Information Paper: *Evidence on Wind Farms and Human Health*, February 2015, National Health and Medical Research Council

[21] AMA Position Statement – *Wind Farms and Health* 2014, Australian Medical Association

[22] https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/everyday-things-emit-radiation/wind-turbine-noise/wind-turbine-noise-health-study-summary-results.html

In 2018, the World Health Organization released the *Environmental Noise Guidelines for the European Region*[23] which concluded:

> *In accordance with the prioritization process, the GDG set a guideline exposure level of 45.0 dB L_{den} for average exposure, based on the relevant increase of the absolute %HA. The GDG stressed that there might be an increased risk for annoyance below this noise exposure level, but it could not state whether there was an increased risk for the other health outcomes below this level owing to a lack of evidence. As the evidence on the adverse effects of wind turbine noise was rated low quality, the GDG made the recommendation conditional.*
>
> [...]
>
> *Based on the low quantity and heterogeneous nature of the evidence, the GDG was not able to formulate a recommendation addressing sleep disturbance due to wind turbine noise at night time.*

As detailed in the MDA paper *WHO Environmental Noise Guidelines for the European Region: conditional recommendation for wind turbine noise in the context of Australian regulations*[24], achieving compliance with NZS 6808 corresponds to noise levels that are consistent with the recommendations of the 2018 WHO European Noise Guidelines.

These findings lend support to the suitability of the wind farm noise controls applied in New South Wales, which are intended to provide reasonable protection of health and amenity at noise sensitive locations.

Further discussions of specific noise considerations related low-frequency sound and infrasound are provided in the following section.

J2 Low frequency noise, infrasound and ground vibration

The limits adopted for the assessment of operational noise from wind farms represent relatively low levels which have been specified in recognition of the quieter rural environments in which wind farms are normally located.

However, consistent with noise policies applied to other forms of development, the criteria are not intended to restrict wind farm noise to inaudible levels. Accordingly, a wind farm which achieves compliance with the criteria may still be audible at surrounding receivers on some occasions; this will depend on a range of factors such as the time of day, the speed and direction of the wind, the proximity to turbines, the extent of vegetation around the dwelling, and the degree to which the dwelling is sheltered from prevailing wind conditions. Irrespective of the relatively low levels which operational wind farm noise is restricted to, an individual's judgement of the audible noise from a wind farm is highly subjective and will be influenced by a range of contextual factors.

The subject of wind farm noise and its characteristics has attracted considerable attention. Specific attention has been directed to alleged matters relating to low frequency sound as well as infrasound and vibration. Low frequency sounds are generally regarded as sounds above 20 Hz and extending upwards into the range of 100-200 Hz. The definition of infrasound often varies in different jurisdictions, but is generally accepted to refer to frequencies of sound which lie below 20 Hz. While 20 Hz is commonly cited as the lower bound of audibility, frequencies below 20 Hz can still be audible, provided that the level of the sound is sufficiently high to exceed the threshold of audibility at those frequencies.

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23 https://www.euro.who.int/en/health-topics/environment-and-health/noise/environmental-noise-guidelines-for-the-european-region

24 http://tinyurl.com/WTN2019-Delaire

In common with many other sources of noise, wind turbines emit infrasound, low frequency sound and ground vibrations. However, what is often overlooked is that these types of sound and vibration are a feature of the everyday environment in which we live and arise from a wide range of natural sources such as the wind and the ocean to man-made sources such as domestic appliances, transportation and agricultural equipment. The important point in relation to wind turbines is that the levels of these types of emissions are low and therefore, in many cases, cannot generally be reliably measured amidst normal background levels.

The NSW Noise Assessment Bulletin states the following concerning infrasound:

> *there is currently no consistent evidence supporting a link between wind energy projects and adverse health outcomes in humans relating to infrasound.*

These types of emissions have been the subject of considerable misrepresentation in media commentary. Notably, the work of Dr Geoff Leventhall, a prominent UK consultant in the field of acoustics and vibration, and researcher in the field of low frequency noise is often cited in some documents which continue to claim concerns about infrasound and low frequency noise from wind turbines. However, Dr Leventhall has regularly made clear statements to assert that there is no significant infrasound from current designs of wind turbines and very little low frequency sound, neither of which are anywhere near the sorts of levels which would represent a direct health risk for neighbouring residents of modern wind farms. An example of such publication, co-authored by Dr Leventhall, was published in the UK Institute of Acoustics Bulletin in March 2009[25]. This publication was prepared as an agreement between acoustic consultants regularly employed on behalf of wind farm developers, and conversely acoustic consultants regularly employed by local councils and community groups campaigning against wind farm developments. The intent of the article was to promote consistent assessment practices, and to assist in restricting wind farm noise disputes to legitimate matters of concern.

On the subject of infrasound and low frequency noise, the article notes:

> *Infrasound is the term generally used to describe sound at frequencies below 20Hz. At separation distances from wind turbines which are typical of residential locations the levels of infrasound from wind turbines are well below the human perception level. Infrasound from wind turbines is often at levels below that of the noise generated by wind around buildings and other obstacles. Sounds at frequencies from about 20Hz to 200Hz are conventionally referred to as low frequency sounds. A report for the DTI in 2006 by Hayes McKenzie concluded that neither infrasound nor low frequency noise was a significant factor at the separation distances at which people lived. This was confirmed by a peer review by a number of consultants working in this field. We concur with this view.*
>
> *A Portuguese group has been researching 'Vibro-acoustic Disease' (VAD) for about 25 years. Their research initially focussed on aircraft technicians who were exposed to very high overall noise levels, typically over 120dB. A range of health problems has been described for the technicians, which the researchers linked to high levels of low frequency noise exposure. However other research has not confirmed this. Wind farms expose people to sound pressure levels orders of magnitude less than the noise levels to which the aircraft technicians were exposed. The Portuguese VAD group has not produced evidence to support their new hypothesis that infrasound and low frequency noise from wind turbines causes similar health effects to those experienced by the aircraft technicians.*

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[25] Institute of Acoustics Bulletin – Bowdler, Bullmore, Davis, Hayes, Jiggins, Leventhall, McKenzie - *Prediction and Assessment of Wind Turbine Noise* –March 2009

Another example of the misrepresentations made in relation to the environmental effects of wind turbines centred around work carried out by Keele University in the UK on ground vibration. Professor Peter Styles and his team at Keele University undertook a study of the effects of wind turbines on the seismic detection array at Eskdalemuir, Scotland. The results of this work were widely misinterpreted and resulted in a statement[26] from Professor Styles:

> *We are writing to clarify some misconceptions [...] about wind farm noise. Whilst it is technically correct that 'vibrations can be picked up as far away as 10km', to give the impression that they can be felt at this distance is highly misleading. The levels of vibration from wind turbines are so small that only the most sophisticated instrumentation and data processing can reveal their presence, and they are almost impossible to detect. The Dunlaw study was designed to measure effects of extremely low level vibration on one of the quietest sites (Eskdalemuir) in the world, and one which houses one of the most sensitive seismic installations in the world. Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background noise – they are not confined to wind turbines. To put the level of vibration into context, they are ground vibrations with amplitudes of about one millionth of a millimetre. There is no possibility of humans sensing the vibration and absolutely no risk to human health. It is, however, an issue for the Eskdalemuir seismic array, as it can detect this level of vibration. It is designed to detect explosions and earthquakes of a low magnitude from all over the world. The infrasound generated by wind turbines can only be detected by the most sensitive equipment, and again this is at levels far below that at which humans will detect the low frequency sound. There is no scientific evidence to suggest that infrasound has an impact on human health.*

More recent measurements[27, 28] have demonstrated that infrasound and low frequency sound produced by regularly encountered natural and man-made sources, such as the infrasound produced by the wind or distant traffic, is comparable to that of modern wind turbines, noting that:

> *Infrasound levels in the rural environment appear to be controlled by localised wind conditions. During low wind periods, levels as low as 40dB(G) were measured at locations both near to and away from wind turbines. At higher wind speeds, infrasound levels of 50 to 70dB(G) were common at both wind farm and non-wind farm sites.*
>
> *Organised shutdowns of the wind farms adjacent to [sic: measurement locations] indicate that there did not appear to be any noticeable contribution from the wind farm to the G-weighted infrasound level measured at either house. This suggests that wind turbines are not a significant source of infrasound at houses located approximately 1.5 kilometres away from wind farm sites*

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26 *Keele University Rejects Renewable Energy Foundation's Low Frequency Noise Research Claims*

27 Sonus report for Pacific Hydro - *Infrasound measurements from wind farms and other sources* – November 2010 See http://www.pacifichydro.com.au/media/192017/infrasound_report.pdf

28 Evans, T., Cooper, J. & Lenchine, V., *Infrasound levels near wind farms and in other environments*, South Australian Environment Protection Authority, Adelaide, 2013 - See https://www.epa.sa.gov.au/files/477912_infrasound.pdf

In 2010, the UK Health Protection Agency published a report[29] on the health effects of exposure to ultrasound and infrasound. The exposures considered in the report related to medical applications and general environmental exposure. The report notes:

> *Infrasound is widespread in modern society, being generated by cars, trains and aircraft, and by industrial machinery, pumps, compressors and low speed fans. Under these circumstances, infrasound is usually accompanied by the generation of audible, low frequency noise. Natural sources of infrasound include thunderstorms and fluctuations in atmospheric pressure, wind and waves, and volcanoes; running and swimming also generate changes in air pressure at infrasonic frequencies.*
>
> *[...]*
>
> *For infrasound, aural pain and damage can occur at exposures above about 140 dB, the threshold depending on the frequency. The best-established responses occur following acute exposures at intensities great enough to be heard and may possibly lead to a decrease in wakefulness. The available evidence is inadequate to draw firm conclusions about potential health effects associated with exposure at the levels normally experienced in the environment, especially the effects of long-term exposures. The available data do not suggest that exposure to infrasound below the hearing threshold levels is capable of causing adverse effects.*

Also, a recent State Government of Victorian Department of Health document[30] concludes the following in relation to infrasound from wind farms:

> *Infrasound is audible when the sound levels are high enough. The hearing threshold for infrasound is much higher than other frequencies. Infrasound from wind farms is at levels well below the hearing threshold and is therefore inaudible to neighbouring residents.*

These studies all indicate that infrasound levels from the proposed Valley of the Winds wind farm are anticipated to be comparable with existing ambient levels.

In February 2015, the National Health and Medical Research Council (NHMRC) released an information paper[31] addressing human health effects of wind farms which includes consideration of noise.

From well over 4,000 articles which were identified during the NHMRC review, only thirteen (13) studies across Europe, North America and Australia satisfied a set of pre-specified eligibility criteria for detailed review and therefore form the basis of the report, which concludes:

> *Examining whether wind farm emissions may affect human health is complex, as both the character of the emissions and individual perceptions of them are highly variable. After careful consideration and deliberation of the body of evidence, NHMRC concludes that there is currently no consistent evidence that wind farms cause adverse health effects in humans. Given the poor quality of current direct evidence and the concern expressed by some members of the community, high quality research into possible health effects of wind farms, particularly within 1,500 metres (m), is warranted.*

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[29] Health Protection Agency UK – *Health Effects of Exposure to Ultrasound and Infrasound – Report of the independent Advisory Group on Non-ionising Radiation* - 2010

[30] *Public Statement: Wind Turbines and Health - July 2010*

[31] *Information Paper - Evidence on Wind Farms and Human Health*, February 2015

The NSW *Noise Assessment Bulletin* issued in December 2016 refers to this advice and states the following in its section on Noise and Health:

> *High levels of noise are associated with adverse health outcomes. To examine this potential relationship the National Health and Medical Research Council (NHMRC) undertook a comprehensive assessment of the scientific evidence on wind farms and human health. In 2015, the NHMRC concluded that "there is no direct evidence that exposure to wind turbine noise affects physical or mental health", and there is currently no consistent evidence supporting a link between wind energy projects and adverse health outcomes in humans relating to infrasound. More specifically, they stated that, "while exposure to environmental noise is associated with health effects, these effects occur at much higher levels of noise than are likely to be perceived by people living in close proximity to wind farms in Australia".*

These studies all indicate that infrasound levels are anticipated to be comparable with existing ambient levels and, as such, are not expected to represent an impact from the proposed wind farm. Similarly, vibration levels from wind turbines are well below perception thresholds, and low frequency levels are typically low.

APPENDIX K TABULATED PREDICTED NOISE LEVEL DATA

Table 32: Predicted noise levels, dB L_{Aeq} - SG 6.2-170

Receiver	Hub-height wind speed, m/s							
	3	4	5	6	7	8	9	≥10
Non-associated receivers								
5	19.7	19.7	22.2	26.1	29.5	32.4	33.7	33.7
18	15.2	15.2	17.7	21.6	25.0	27.9	29.2	29.2
25	18.5	18.5	21.0	24.9	28.3	31.2	32.5	32.5
76	18.5	18.5	21.0	24.9	28.3	31.2	32.5	32.5
77	17.9	17.9	20.4	24.3	27.7	30.6	31.9	31.9
79	17.4	17.4	19.9	23.8	27.2	30.1	31.4	31.4
82	16.7	16.7	19.2	23.1	26.5	29.4	30.7	30.7
83	16.2	16.2	18.7	22.6	26.0	28.9	30.2	30.2
84	17.4	17.4	19.9	23.8	27.2	30.1	31.4	31.4
85	18.5	18.5	21.0	24.9	28.3	31.2	32.5	32.5
86	18.6	18.6	21.1	25.0	28.4	31.3	32.6	32.6
87	17.3	17.3	19.8	23.7	27.1	30.0	31.3	31.3
88	18.3	18.3	20.8	24.7	28.1	31.0	32.3	32.3
90	17.8	17.8	20.3	24.2	27.6	30.5	31.8	31.8
91	17.7	17.7	20.2	24.1	27.5	30.4	31.7	31.7
127	15.9	15.9	18.4	22.3	25.7	28.6	29.9	29.9
151	15.1	15.1	17.6	21.5	24.9	27.8	29.1	29.1
180	15.4	15.4	17.9	21.8	25.2	28.1	29.4	29.4
181	15.8	15.8	18.3	22.2	25.6	28.5	29.8	29.8
182	16.1	16.1	18.6	22.5	25.9	28.8	30.1	30.1
187	13.0	13.0	15.5	19.4	22.8	25.7	27.0	27.0
189	13.4	13.4	15.9	19.8	23.2	26.1	27.4	27.4
190	14.1	14.1	16.6	20.5	23.9	26.8	28.1	28.1
199	16.9	16.9	19.4	23.3	26.7	29.6	30.9	30.9
239	15.7	15.7	18.2	22.1	25.5	28.4	29.7	29.7
240	14.8	14.8	17.3	21.2	24.6	27.5	28.8	28.8
278	19.2	19.2	21.7	25.6	29.0	31.9	33.2	33.2
282	18.9	18.9	21.4	25.3	28.7	31.6	32.9	32.9
298	16.7	16.7	19.2	23.1	26.5	29.4	30.7	30.7

Receiver	Hub-height wind speed, m/s							
	3	**4**	**5**	**6**	**7**	**8**	**9**	**≥10**
314	17.3	17.3	19.8	23.7	27.1	30.0	31.3	31.3
324	15.3	15.3	17.8	21.7	25.1	28.0	29.3	29.3
363	13.8	13.8	16.3	20.2	23.6	26.5	27.8	27.8
497	19.2	19.2	21.7	25.6	29.0	31.9	33.2	33.2
503	15.1	15.1	17.6	21.5	24.9	27.8	29.1	29.1
505	16.6	16.6	19.1	23.0	26.4	29.3	30.6	30.6
Associated receivers								
4	18.9	18.9	21.4	25.3	28.7	31.6	32.9	32.9
6	16.9	16.9	19.4	23.3	26.7	29.6	30.9	30.9
89	18.6	18.6	21.1	25.0	28.4	31.3	32.6	32.6
246	15.2	15.2	17.7	21.6	25.0	27.9	29.2	29.2
250	27.1	27.1	29.6	33.5	36.9	39.8	41.1	41.1
251	18.7	18.7	21.2	25.1	28.5	31.4	32.7	32.7
252	18.7	18.7	21.2	25.1	28.5	31.4	32.7	32.7
253	18.1	18.1	20.6	24.5	27.9	30.8	32.1	32.1
254	19.0	19.0	21.5	25.4	28.8	31.7	33.0	33.0
256	22.7	22.7	25.2	29.1	32.5	35.4	36.7	36.7
257	23.7	23.7	26.2	30.1	33.5	36.4	37.7	37.7
258	24.8	24.8	27.3	31.2	34.6	37.5	38.8	38.8
280	19.3	19.3	21.8	25.7	29.1	32.0	33.3	33.3
281	20.0	20.0	22.5	26.4	29.8	32.7	34.0	34.0
297	27.1	27.1	29.6	33.5	36.9	39.8	41.1	41.1
303	25.1	25.1	27.6	31.5	34.9	37.8	39.1	39.1
304	21.6	21.6	24.1	28.0	31.4	34.3	35.6	35.6
305	17.7	17.7	20.2	24.1	27.5	30.4	31.7	31.7
306	19.6	19.6	22.1	26.0	29.4	32.3	33.6	33.6
309	21.5	21.5	24.0	27.9	31.3	34.2	35.5	35.5
310	20.3	20.3	22.8	26.7	30.1	33.0	34.3	34.3
329	20.5	20.5	23.0	26.9	30.3	33.2	34.5	34.5

Table 33: Predicted noise levels, dB L_{Aeq} – GE 6.0-164

Receiver	Hub-height wind speed, m/s						
	3	**4**	**5**	**6**	**7**	**8**	**9**	**≥10**
Non-associated receivers								
5	-	22.0	23.9	27.4	30.7	32.9	34.9	35.2
18	-	17.2	19.1	22.6	25.9	28.1	30.1	30.4
25	-	20.7	22.6	26.1	29.4	31.6	33.6	33.9
76	-	20.6	22.5	26.0	29.3	31.5	33.5	33.8
77	-	20.0	21.9	25.4	28.7	30.9	32.9	33.2
79	-	19.6	21.5	25.0	28.3	30.5	32.5	32.8
82	-	18.7	20.6	24.1	27.4	29.6	31.6	31.9
83	-	18.2	20.1	23.6	26.9	29.1	31.1	31.4
84	-	19.5	21.4	24.9	28.2	30.4	32.4	32.7
85	-	20.7	22.6	26.1	29.4	31.6	33.6	33.9
86	-	20.8	22.7	26.2	29.5	31.7	33.7	34.0
87	-	19.3	21.2	24.7	28.0	30.2	32.2	32.5
88	-	20.4	22.3	25.8	29.1	31.3	33.3	33.6
90	-	19.8	21.7	25.2	28.5	30.7	32.7	33.0
91	-	19.6	21.5	25.0	28.3	30.5	32.5	32.8
127	-	18.0	19.9	23.4	26.7	28.9	30.9	31.2
151	-	17.3	19.2	22.7	26.0	28.2	30.2	30.5
180	-	17.5	19.4	22.9	26.2	28.4	30.4	30.7
181	-	18.0	19.9	23.4	26.7	28.9	30.9	31.2
182	-	18.3	20.2	23.7	27.0	29.2	31.2	31.5
187	-	15.1	17.0	20.5	23.8	26.0	28.0	28.3
189	-	15.6	17.5	21.0	24.3	26.5	28.5	28.8
190	-	16.3	18.2	21.7	25.0	27.2	29.2	29.5
199	-	19.0	20.9	24.4	27.7	29.9	31.9	32.2
239	-	17.8	19.7	23.2	26.5	28.7	30.7	31.0
240	-	16.8	18.7	22.2	25.5	27.7	29.7	30.0
278	-	21.4	23.3	26.8	30.1	32.3	34.3	34.6
282	-	21.0	22.9	26.4	29.7	31.9	33.9	34.2
298	-	18.6	20.5	24.0	27.3	29.5	31.5	31.8
314	-	19.3	21.2	24.7	28.0	30.2	32.2	32.5

Receiver	Hub-height wind speed, m/s							
	3	**4**	**5**	**6**	**7**	**8**	**9**	**≥10**
324	-	17.5	19.4	22.9	26.2	28.4	30.4	30.7
363	-	15.8	17.7	21.2	24.5	26.7	28.7	29.0
497	-	21.4	23.3	26.8	30.1	32.3	34.3	34.6
503	-	17.2	19.1	22.6	25.9	28.1	30.1	30.4
505	-	18.7	20.6	24.1	27.4	29.6	31.6	31.9
Associated receivers								
4	-	21.0	22.9	26.4	29.7	31.9	33.9	34.2
6	-	18.9	20.8	24.3	27.6	29.8	31.8	32.1
89	-	20.6	22.5	26.0	29.3	31.5	33.5	33.8
246	-	17.3	19.2	22.7	26.0	28.2	30.2	30.5
250	-	29.6	31.5	35.0	38.3	40.5	42.5	42.8
251	-	20.8	22.7	26.2	29.5	31.7	33.7	34.0
252	-	20.9	22.8	26.3	29.6	31.8	33.8	34.1
253	-	20.3	22.2	25.7	29.0	31.2	33.2	33.5
254	-	21.3	23.2	26.7	30.0	32.2	34.2	34.5
256	-	25.2	27.1	30.6	33.9	36.1	38.1	38.4
257	-	26.1	28.0	31.5	34.8	37.0	39.0	39.3
258	-	27.3	29.2	32.7	36.0	38.2	40.2	40.5
280	-	21.4	23.3	26.8	30.1	32.3	34.3	34.6
281	-	22.3	24.2	27.7	31.0	33.2	35.2	35.5
297	-	29.5	31.4	34.9	38.2	40.4	42.4	42.7
303	-	27.7	29.6	33.1	36.4	38.6	40.6	40.9
304	-	24.1	26.0	29.5	32.8	35.0	37.0	37.3
305	-	20.2	22.1	25.6	28.9	31.1	33.1	33.4
306	-	22.1	24.0	27.5	30.8	33.0	35.0	35.3
309	-	24.0	25.9	29.4	32.7	34.9	36.9	37.2
310	-	22.6	24.5	28.0	31.3	33.5	35.5	35.8
329	-	22.7	24.6	28.1	31.4	33.6	35.6	35.9

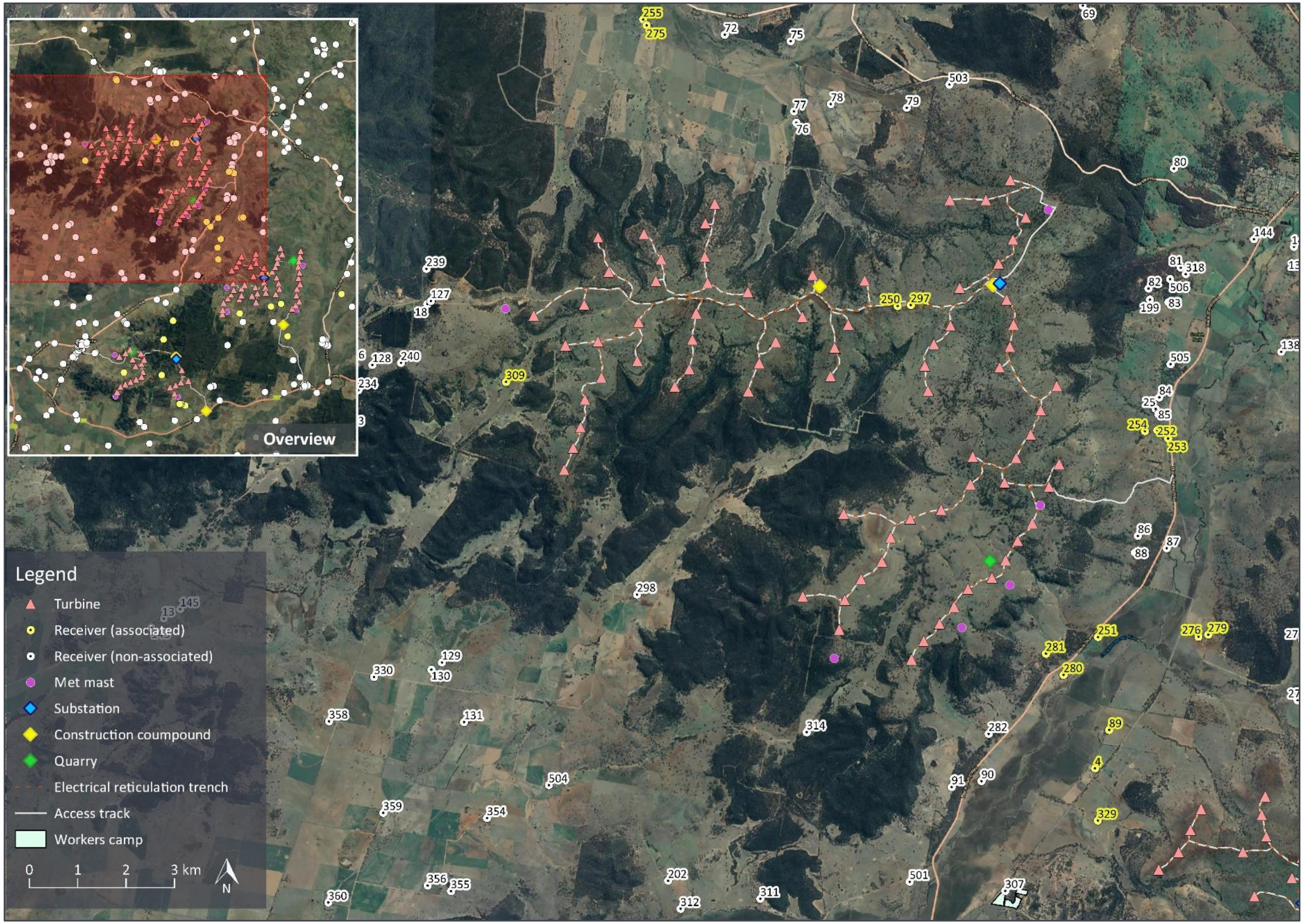
Table 34: Predicted noise levels at receivers, dB L_{Aeq} – V162-6.2 MW

Receiver	Hub-height wind speed, m/s						
	3	4	5	6	7	8	9	≥10
Non-associated receivers								
5	-	23.4	23.6	25.5	28.5	31.3	33.6	34.1
18	-	18.7	18.9	20.8	23.8	26.6	28.9	29.4
25	-	22.1	22.3	24.2	27.2	30.0	32.3	32.8
76	-	22.1	22.3	24.2	27.2	30.0	32.3	32.8
77	-	21.6	21.8	23.7	26.7	29.5	31.8	32.3
79	-	21.1	21.3	23.2	26.2	29.0	31.3	31.8
82	-	20.2	20.4	22.3	25.3	28.1	30.4	30.9
83	-	19.8	20.0	21.9	24.9	27.7	30.0	30.5
84	-	21.0	21.2	23.1	26.1	28.9	31.2	31.7
85	-	22.1	22.3	24.2	27.2	30.0	32.3	32.8
86	-	22.2	22.4	24.3	27.3	30.1	32.4	32.9
87	-	20.9	21.1	23.0	26.0	28.8	31.1	31.6
88	-	21.9	22.1	24.0	27.0	29.8	32.1	32.6
90	-	21.3	21.5	23.4	26.4	29.2	31.5	32.0
91	-	21.2	21.4	23.3	26.3	29.1	31.4	31.9
127	-	19.5	19.7	21.6	24.6	27.4	29.7	30.2
151	-	18.7	18.9	20.8	23.8	26.6	28.9	29.4
180	-	18.9	19.1	21.0	24.0	26.8	29.1	29.6
181	-	19.4	19.6	21.5	24.5	27.3	29.6	30.1
182	-	19.7	19.9	21.8	24.8	27.6	29.9	30.4
187	-	16.6	16.8	18.7	21.7	24.5	26.8	27.3
189	-	17.0	17.2	19.1	22.1	24.9	27.2	27.7
190	-	17.7	17.9	19.8	22.8	25.6	27.9	28.4
199	-	20.5	20.7	22.6	25.6	28.4	30.7	31.2
239	-	19.3	19.5	21.4	24.4	27.2	29.5	30.0
240	-	18.4	18.6	20.5	23.5	26.3	28.6	29.1
278	-	22.8	23.0	24.9	27.9	30.7	33.0	33.5
282	-	22.4	22.6	24.5	27.5	30.3	32.6	33.1
298	-	20.2	20.4	22.3	25.3	28.1	30.4	30.9
314	-	20.8	21.0	22.9	25.9	28.7	31.0	31.5

Receiver	Hub-height wind speed, m/s							
	3	4	5	6	7	8	9	≥10
324	-	18.9	19.1	21.0	24.0	26.8	29.1	29.6
363	-	17.3	17.5	19.4	22.4	25.2	27.5	28.0
497	-	22.9	23.1	25.0	28.0	30.8	33.1	33.6
503	-	18.6	18.8	20.7	23.7	26.5	28.8	29.3
505	-	20.2	20.4	22.3	25.3	28.1	30.4	30.9
Associated receivers								
4	-	22.5	22.7	24.6	27.6	30.4	32.7	33.2
6	-	20.4	20.6	22.5	25.5	28.3	30.6	31.1
89	-	22.2	22.4	24.3	27.3	30.1	32.4	32.9
246	-	18.8	19.0	20.9	23.9	26.7	29.0	29.5
250	-	30.6	30.8	32.7	35.7	38.5	40.8	41.3
251	-	22.3	22.5	24.4	27.4	30.2	32.5	33.0
252	-	22.3	22.5	24.4	27.4	30.2	32.5	33.0
253	-	21.7	21.9	23.8	26.8	29.6	31.9	32.4
254	-	22.6	22.8	24.7	27.7	30.5	32.8	33.3
256	-	26.3	26.5	28.4	31.4	34.2	36.5	37.0
257	-	27.3	27.5	29.4	32.4	35.2	37.5	38.0
258	-	28.3	28.5	30.4	33.4	36.2	38.5	39.0
280	-	22.9	23.1	25.0	28.0	30.8	33.1	33.6
281	-	23.6	23.8	25.7	28.7	31.5	33.8	34.3
297	-	30.5	30.7	32.6	35.6	38.4	40.7	41.2
303	-	28.6	28.8	30.7	33.7	36.5	38.8	39.3
304	-	25.2	25.4	27.3	30.3	33.1	35.4	35.9
305	-	21.3	21.5	23.4	26.4	29.2	31.5	32.0
306	-	23.1	23.3	25.2	28.2	31.0	33.3	33.8
309	-	25.1	25.3	27.2	30.2	33.0	35.3	35.8
310	-	23.5	23.7	25.6	28.6	31.4	33.7	34.2
329	-	24.1	24.3	26.2	29.2	32.0	34.3	34.8

APPENDIX L CONSTRUCTION LAYOUT PLAN

Figure 12: Proposed layout of construction compounds, site access routes, cable routes and receivers – Mount Hope cluster



MARSHALL DAY Acoustics

Figure 13: Proposed layout of construction compounds, site access routes, cable routes and receivers – Girragulang Road cluster

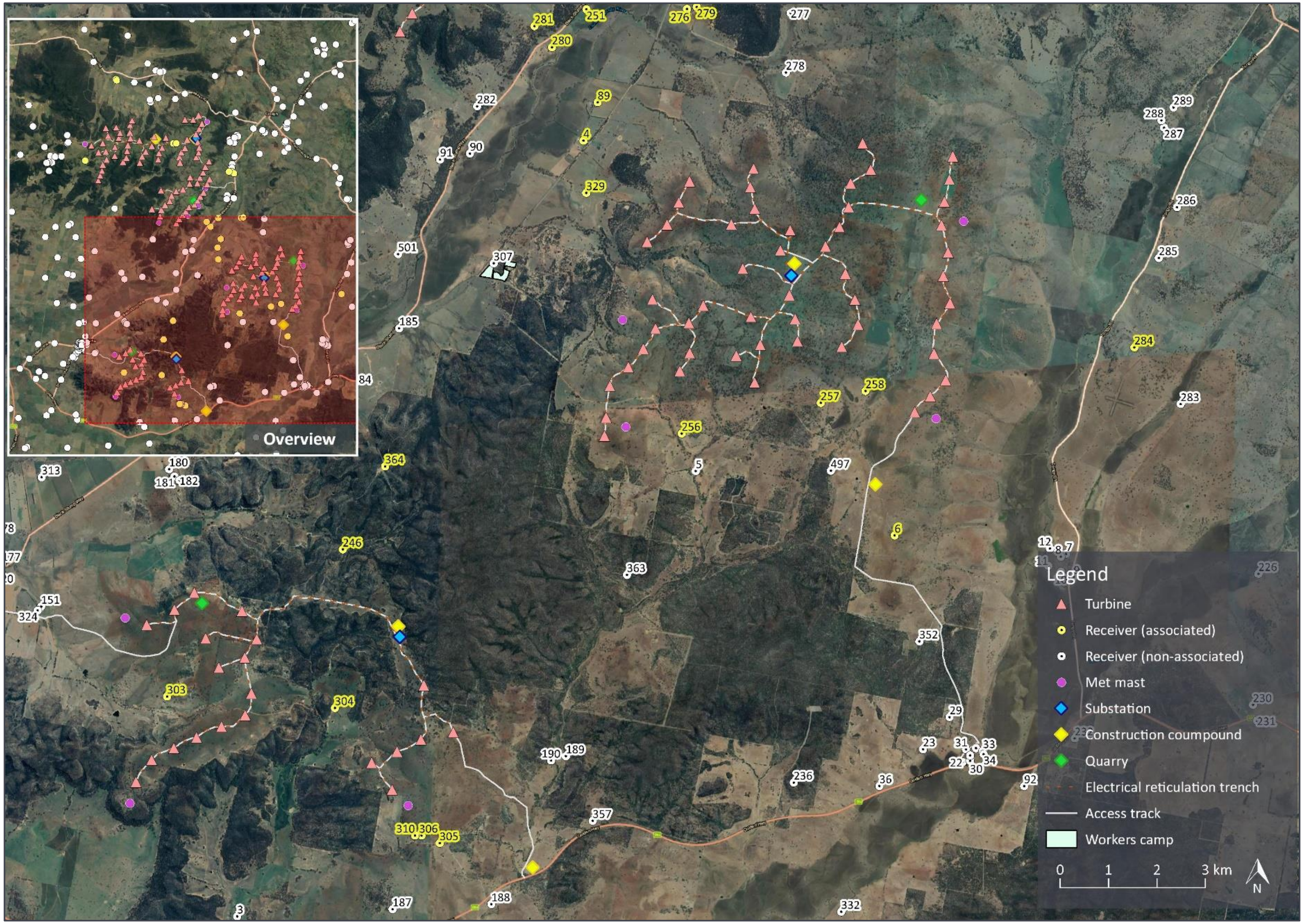
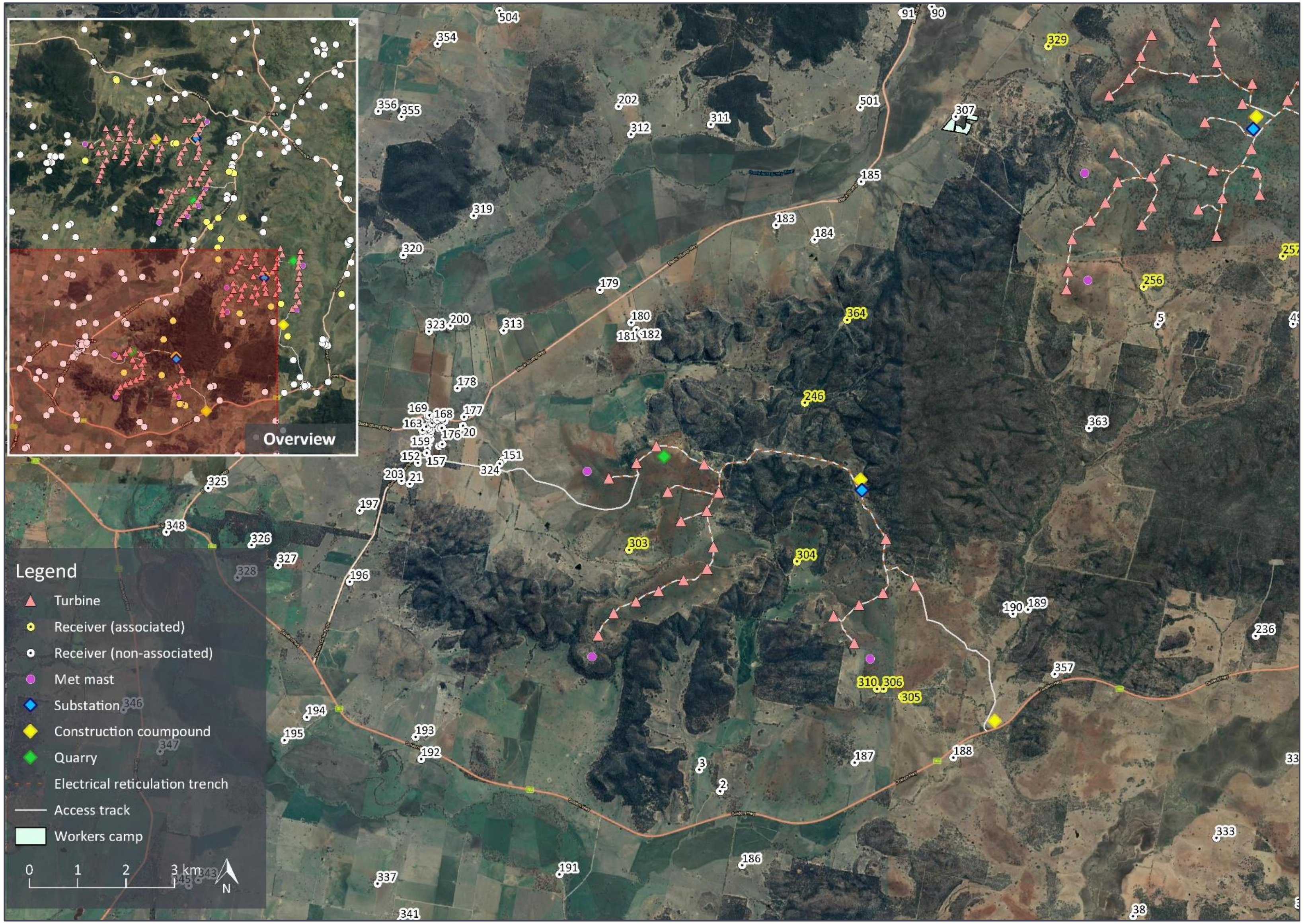


Figure 14: Proposed layout of construction compounds, site access routes, cable routes and receivers – Leadville cluster



APPENDIX M CONSTRUCTION EQUIPMENT, WORK STAGES AND ACOUSTIC DATA

It is anticipated that a variety of construction equipment would be used for this project.

Sound power levels for the types of equipment used to construct a wind farm have been determined from guidance and data sources including Australian Standard AS 2436:2010 *Guide to noise and vibration control on construction, demolition and maintenance sites* (AS 2436), and noise level data from previous projects of a similar nature.

Table 35 summarises the noise emissions used to represent key items of plant associated with construction.

Table 35: Construction noise sources sound power data, dB L_{WA}

Noise source	Sound power level
Excavator fitted with pneumatic breaker	118
Excavator (100 to 200 kW)	107
Tracked loaders	115
Crane (200 t)	105
Crane (500 t)	110
Crane (1,200 t)	115
Delivery Trucks	107
Concrete trucks	108
Dump truck	117
Concrete pump	108
Generator	99
Grader	110
Bulldozer	108
Rock Crusher	120
Batching Plant	110
Cone crusher	116
Impact crusher	118
Jaw crusher	116
Screening plant	109
Water truck	107

Overall aggregated total sound power levels for key construction tasks have been determined on the basis of a typical schedule of equipment associated with each task. The actual equipment choices and equipment numbers for each task are not presently defined in detail, and therefore the schedule of equipment listed here does not represent a final or definitive list of plant. The equipment schedule is therefore presented solely as an indication of construction noise levels.

The overall total aggregated sound power levels for each of the key construction tasks are detailed in Table 36, and assume that each item of plant associated with a task operates simultaneously for the entire duration of an assessment period.

Table 36: Overall sound power levels of key construction tasks, dB L_{WA}

Construction task	Plant/Equipment	Approximate overall sound power level
Access road construction	2x Excavator (100 to 200 kW), 1x Tracked loaders, 2x Dump truck, 1x Grader, 1x Bulldozer	120
Cable trench digging	1x Excavator (100 to 200 kW), 1x Dump truck, 1x Generator, 1x Bulldozer	120
Concrete batching plant	1x Concrete trucks, 1x Concrete pump, 1x Batching Plant	110
Site compound construction	1x Excavator (100 to 200 kW), 1x Crane (200 t), 1x Delivery Trucks, 1x Concrete trucks, 1x Concrete pump, 1x Generator, 1x Bulldozer, 1x Rock Crusher	120
Substation construction	1x Excavator (100 to 200 kW), 1x Crane (500 t), 1x Delivery Trucks, 1x Concrete trucks, 1x Concrete pump, 1x Generator, 1x Bulldozer	115
BESS construction	1x Excavator (100 to 200 kW), 1x Crane (500 t), 1x Delivery Trucks, 1x Concrete trucks, 1x Concrete pump, 1x Generator, 1x Bulldozer	115
Turbine foundations	1x Excavator fitted with pneumatic breaker, 1x Excavator (100 to 200 kW), 1x Crane (200 t), 1x Delivery Trucks, 1x Concrete trucks, 1x Concrete pump, 1x Generator, 1x Bulldozer	120
Turbine assembly	2x Crane (200 t), 2x Crane (500 t), 1x Crane (1,200 t), 1x Generator	120
Gravel quarry	1x Cone crusher, 1x Dump truck, 1x Excavator, 1x Impact crusher, 1x Jaw crusher, 2x Screening plant, 1x Water truck	125

APPENDIX N NSW NOISE ASSESSMENT BULLETIN – INFORMATION REQUIREMENTS

The NSW Noise Assessment Bulletin specifies the minimum, information to be provided in a noise report accompanying and Environmental Impact Statement. The requirements and the location with this report where the requirement is addressed, are summarised in Table

Table 37: NSW Noise Assessment Bulletin – information requirements

Information requirement	Location of relevant content
• *the model used to predict the wind energy project noise levels and input assumptions and factors used in the model, noting that noise management mode or sector management (i.e. stopping individual turbines or combinations, or operating in low noise mode, during identified meteorological conditions) should not be used in the primary modelling or predicting of noise levels. Any modelling and predictions which incorporate noise management mode or sector management must be reported separately;*	Section 3.1 Appendix F
• *background noise measurement locations including time and duration of the background noise monitoring program;*	Figure 1 to Figure 3 See also Background noise report
• *wind speed monitoring locations within the project area, heights above ground and graphical correlation plot of hub height wind speed versus background noise level data;*	See Background noise report
• *a summary of the environmental noise criteria for the project at each integer wind speed based on the above correlation;*	Appendix H See also Background noise report
• *make and model of the representative wind turbine(s) along with the positions of the wind turbines;*	Figure 1 to Figure 3 Section 5.2 Appendix C
• *predicted noise levels at the closest non-associated dwellings to the wind energy project at each integer wind speed;*	Section 5.4 Appendix K
• *a comparison of the predicted noise levels against the criterion at each integer wind speed for the closest non-associated dwellings to the wind energy project; and*	Section 5.4
• *modifications or operating strategy that would be employed to address any unforeseen non-compliances. The error margins of the noise model used should be considered in developing such modifications or strategies.*	Section 7.0